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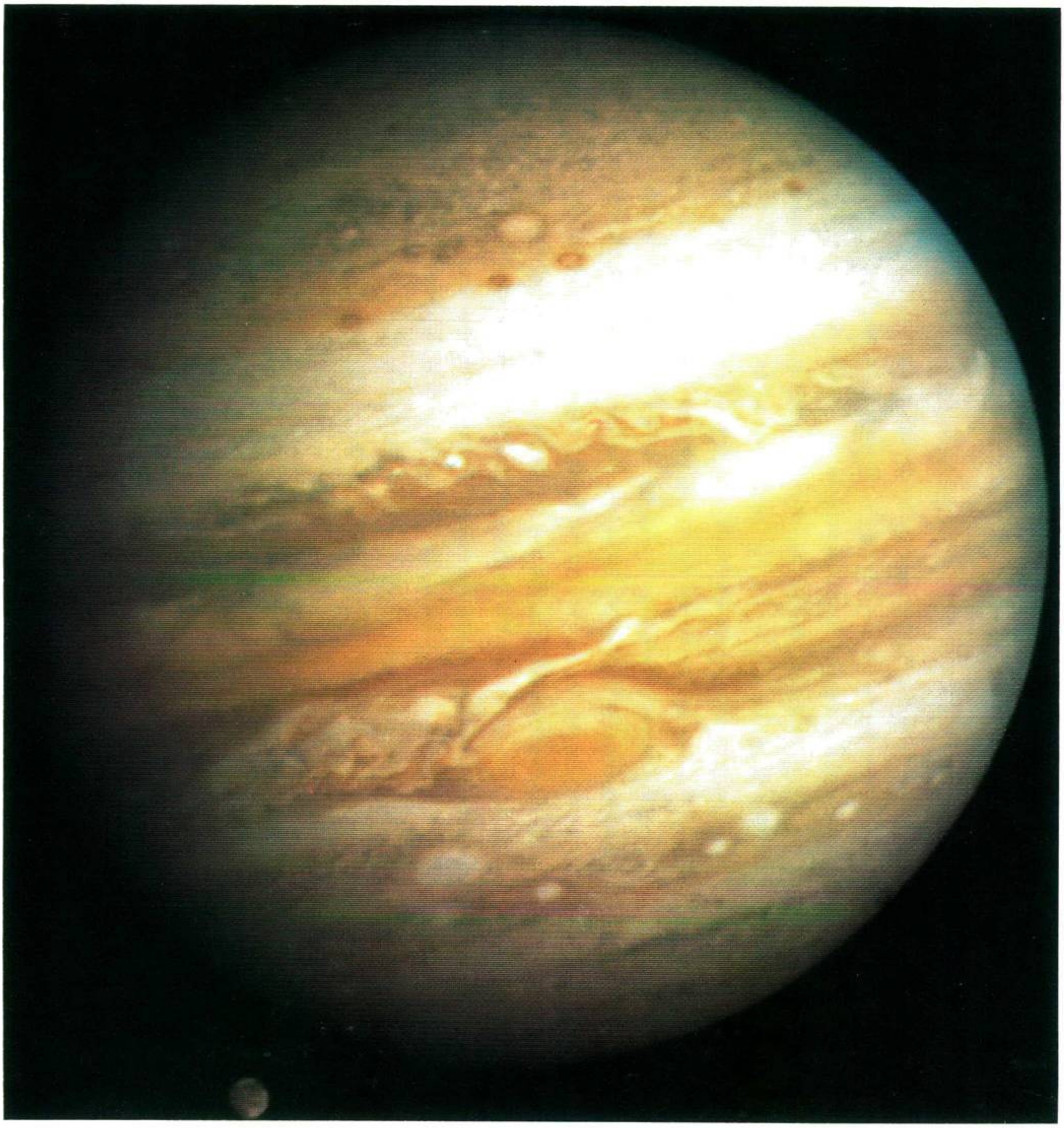

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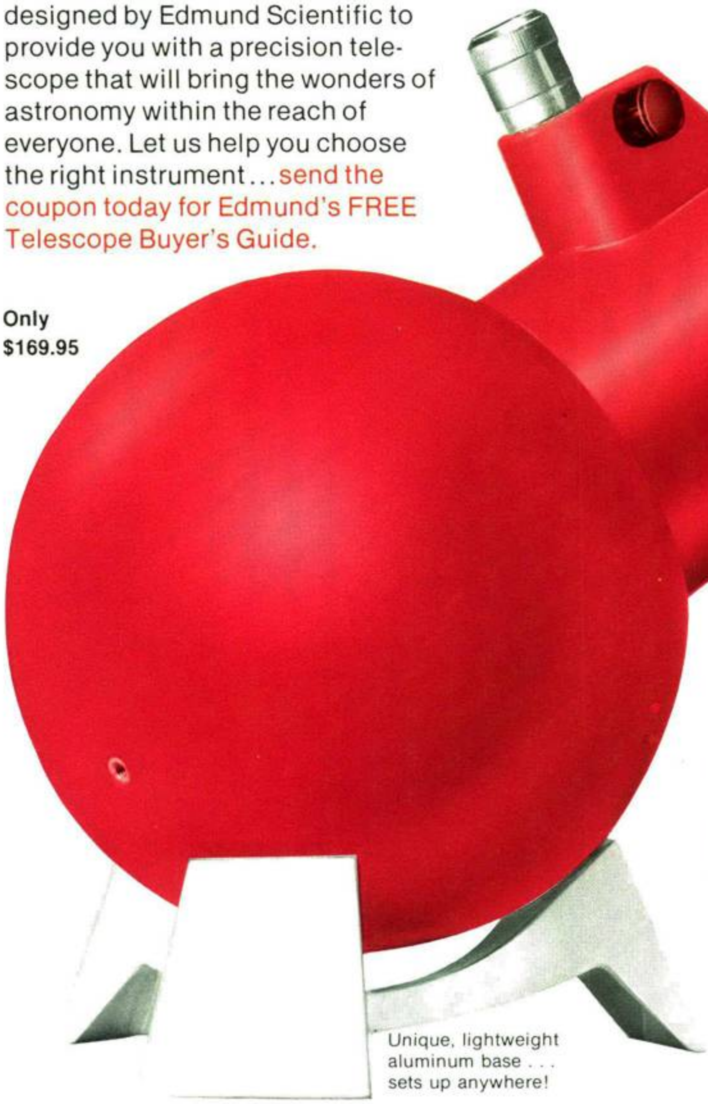

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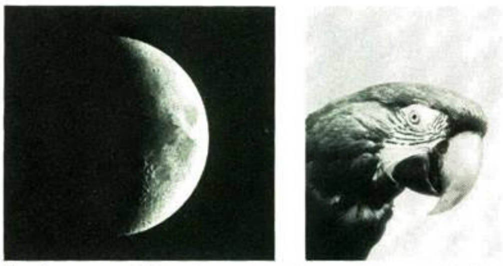

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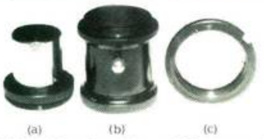

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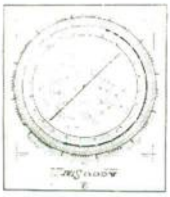

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ASTRONOMY

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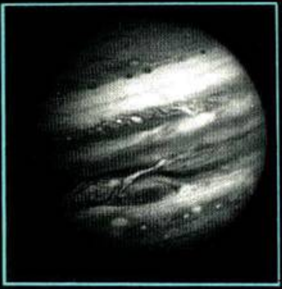

COVER: As it approaches, Voyager 1 sees more and more detail in the turbulent clouds and fascinating moons of the giant planet Jupiter. In this photograph, taken January 24 from a range of 25 million miles, the Red Spot shows prominently below center, while Ganymede, Jupiter's largest satellite, can be seen to the lower left of the planet. The Red Spot is surrounded by an extraordinarily complex region of rapidly changing clouds and violent motions, and the Red Spot itself is swirling counterclockwise with a period of about six days. Jet Propulsion Laboratory/NASA photograph 1-9.

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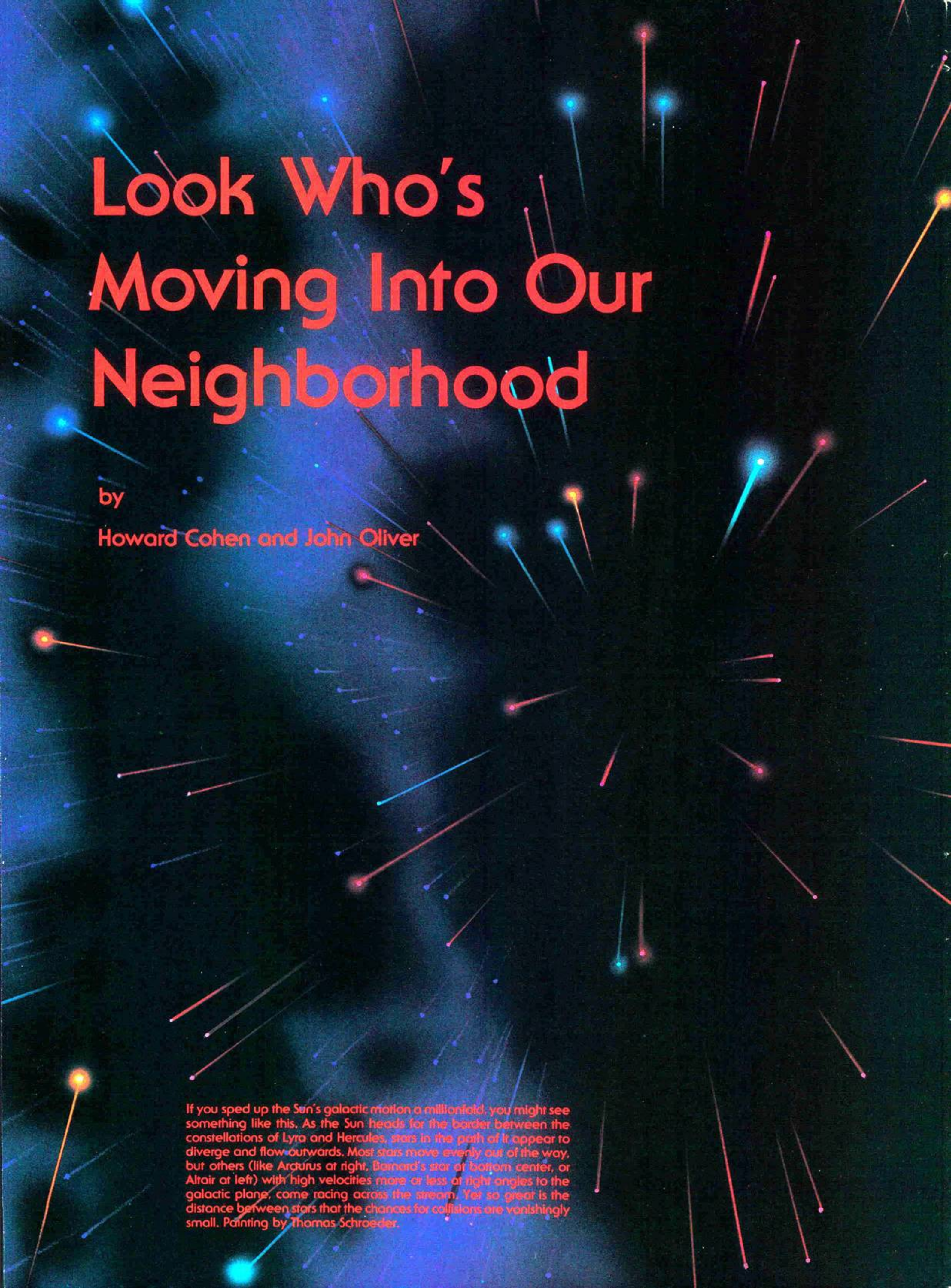
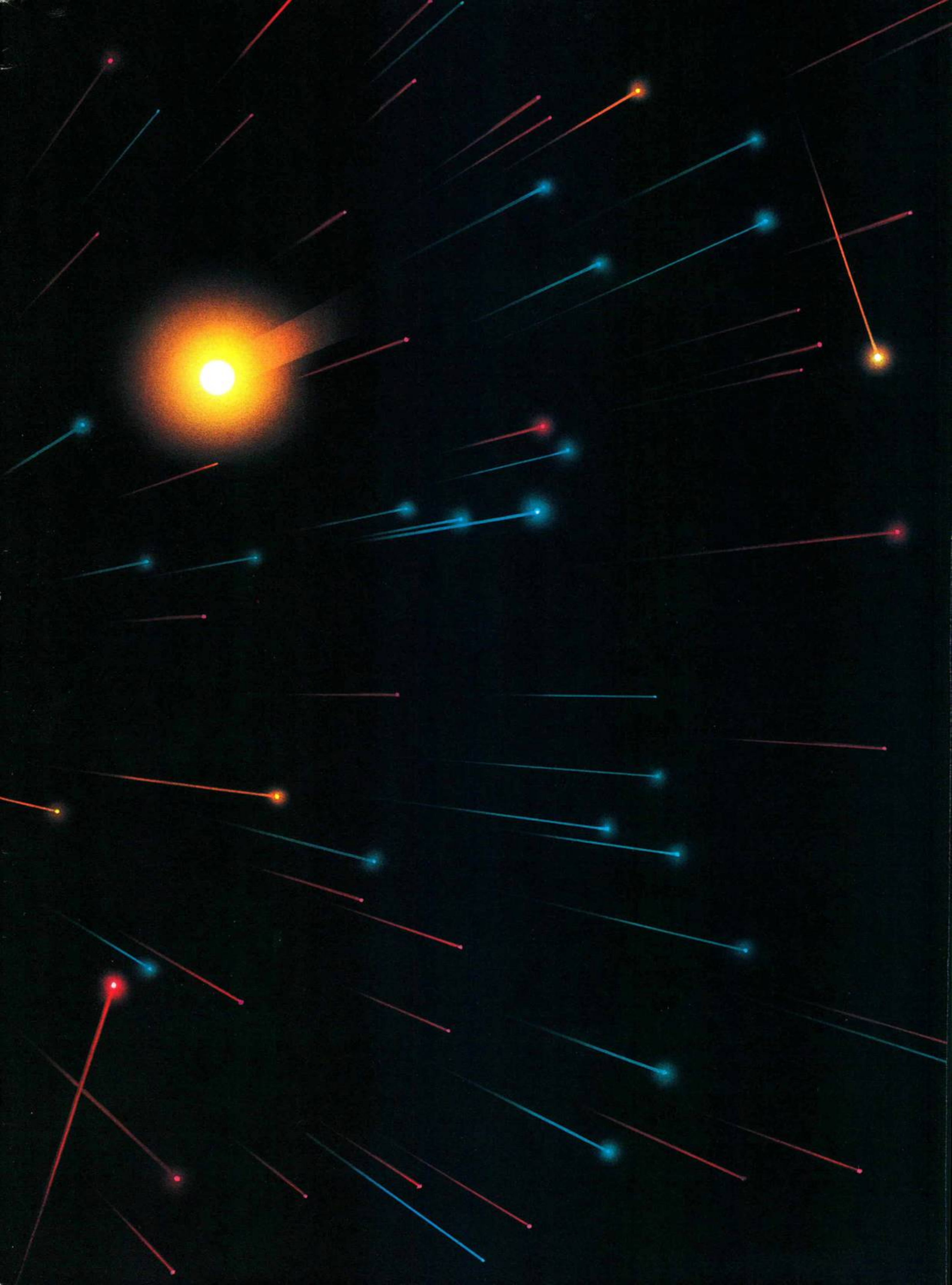
Look Who's Moving Into Our Neighborhood

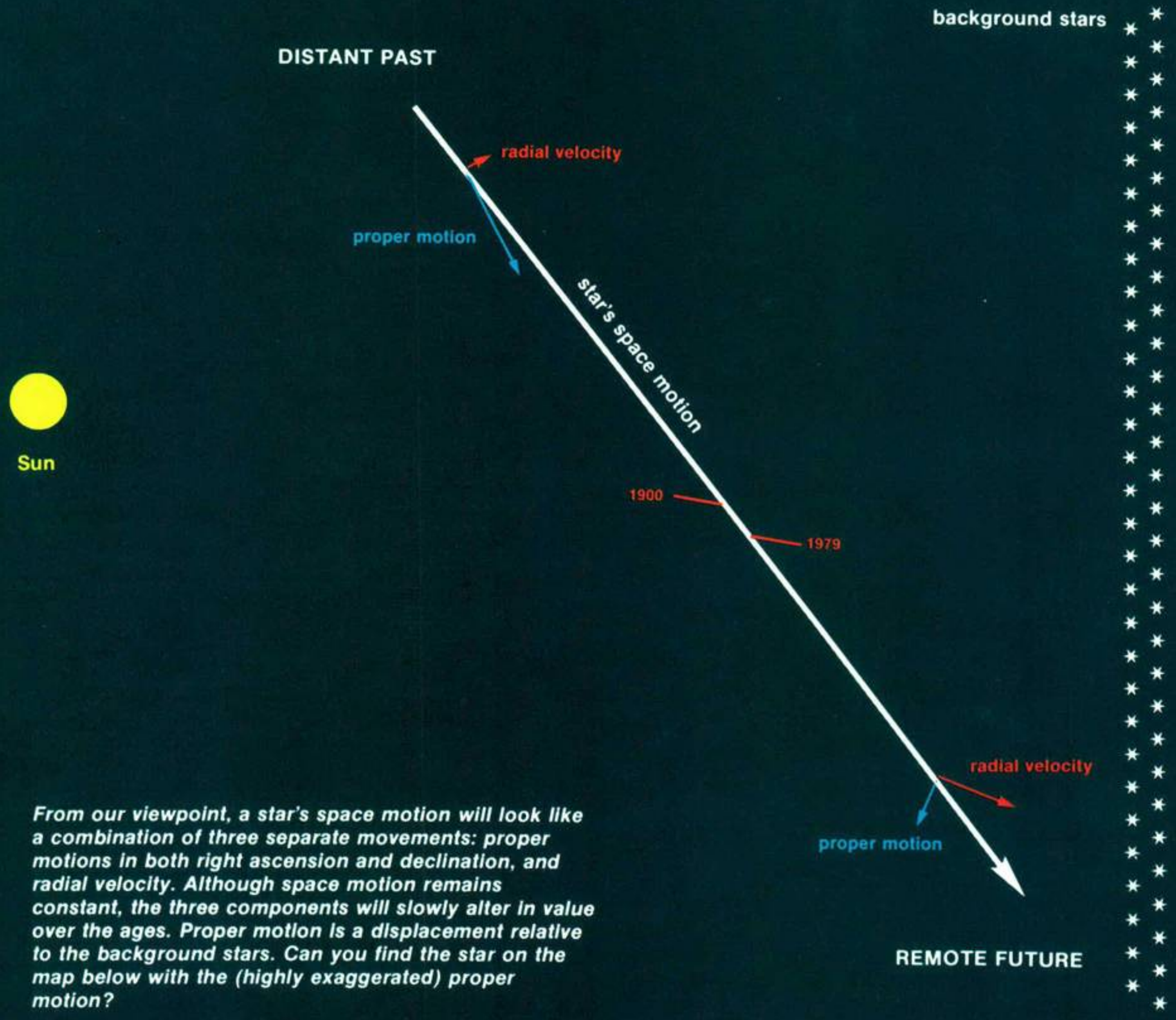
by

Howard Cohen and John Oliver



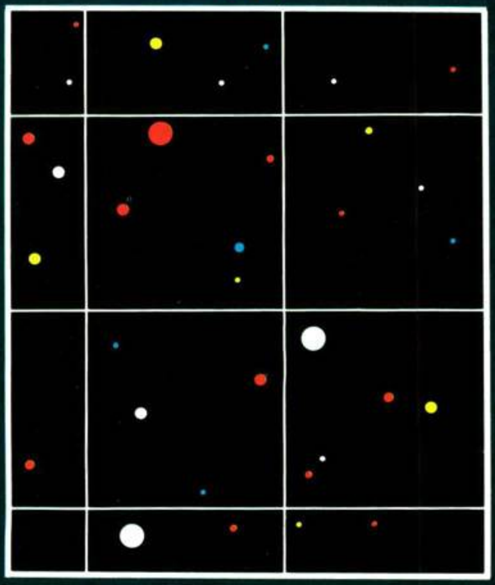
If you sped up the Sun's galactic motion a millionfold, you might see something like this. As the Sun heads for the border between the constellations of Lyra and Hercules, stars in the path of it appear to diverge and flow outwards. Most stars move evenly out of the way, but others (like Arcturus at right, Barnard's star at bottom center, or Altair at left) with high velocities more or less at right angles to the galactic plane, come racing across the stream. Yet so great is the distance between stars that the chances for collisions are vanishingly small. Painting by Thomas Schroeder.



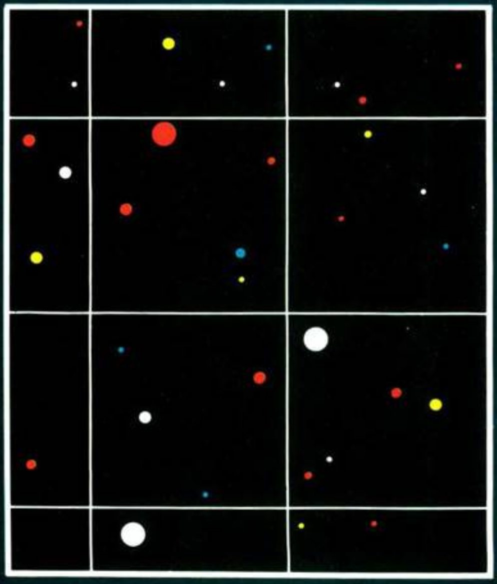

background stars
DISTANT PAST
radial velocity
proper motion
star's space motion
Sun
1900
1979
radial velocity
proper motion
REMOTE FUTURE

From our viewpoint, a star's space motion will look like a combination of three separate movements: proper motions in both right ascension and declination, and radial velocity. Although space motion remains constant, the three components will slowly alter in value over the ages. Proper motion is a displacement relative to the background stars. Can you find the star on the map below with the (highly exaggerated) proper motion?

1900



1979



To an ancient Greek, the stars in the heavens were unmoving and fixed in their places. Two thousand years later, when Copernicus had set the Earth in motion, there was still no need to adjust the constellation figures. When you go outside tonight and look up, the patterns you see are the same as those seen by your ancestors long ago. The aspect of the sky changes so slowly that even planetariums, which boast of being space and time machines, have no provision for altering the familiar constellations.

Special effects projectors may take us to other worlds, but the starry backdrop remains the same: the Big Dipper is there, Orion is there, all the customary signposts are in their places. And why not? Although modern astronomy has learned a great deal about the swiftness of stellar motions as they circle the galactic hub, even the Sun itself has orbited the Galaxy's nucleus but 20 times during its own existance.

Yet between the lifespan of a human being and that of his Sun are ages of geologic history which have seen significant changes in the heavens. The slow, almost imperceptible, yearly changes in a star's apparent position (known as *proper motion*) will ultimately cause tonight's constellations to become unrecognizable. The familiar Big Dipper of our northern skies is not as old as Man himself. Orion, famed hunter of the winter, surely predates written history, but, like all the current constellations, he too must have been unknown to early Man.

Less often remembered however, are other long-term effects of stellar motion. Ultimately, stars' changing distances will slowly alter their brightnesses and their radial and tangential velocities, as well as their proper motions. Stars far away but approaching will come stealthily out of the night like a motorcycle's headlight on a dark back road. Initially, the space motion of such a star will appear nearly all radial (in the line of sight) as if a head-on collision were likely; there will be little or no observed proper motion. As the star advances with increasing brightness, tangential (sideways) drift should grow at the expense of radial velocity. When it comes closest to us, there should be no radial velocity at all, for its entire space motion will be transverse. The star will then shine at its "momentary" brightest, sweeping past silently in front of the background stars. Over immeasurable centuries it will recede into the distance, its radial velocity growing slowly back, as the tangential motion dwindles.

Perhaps it's silly to consider events spanning eons, yet the consequences of nearby stellar motions are thought-provoking. Let's pose a few "what-ifs": have close stellar approaches been responsible for disturbing the vast swarms of comets believed to orbit our Sun halfway to the nearest stars? Such encounters may be the reason new comets periodically orbit inward to the Sun. Is it possible that within the span of humankind's existence there have been star systems significantly closer or brighter than now? If the velocity of light is unattainable, and warp drives an SF fantasy, could future stellar visitations to our neighborhood make star-travel more feasible? Or are there ancient memories, buried in some collective unconscious, of extraordinarily bright stars shifting slowly across the heavens — perhaps over a single lifetime?

But aren't such thoughts nothing more than the "stuff dreams are made on," since stellar distances are so vast? Maybe, maybe not, but consider those stars already in our close vicinity. If an object moves relative to the Sun at even a modest 10 km per second, it'll travel 33 light-years in only a million years' time. Since stellar motions of this amount are common enough, and since hundreds of stars are known within 30 to 50 light-years, many suns could have moved into our neighborhood since the time manlike creatures first walked the Earth.

At present, the closest known stars belong to the Alpha Centauri system, 4.3 light-years away. (To help you get a grip on relative distances, think of a light-year as a mile. Then to the same scale, the Earth-Sun distance, called the astronomical unit, is an inch.) Although these stars are currently approaching us, nothing very remarkable will happen when they come their closest in about 30,000 A.D., for the separation distance will have only decreased to 3 light-years. Sirius, now our brightest star, is also nearly at closest approach and will consequently brighten by just a fifth of a magnitude over the next 60 centuries. More interesting is Barnard's star, the star with the highest-known proper motion: 10½ seconds of arc per year. At this rate it can span the angular extent of the Moon in only 180 years! Barnard's star is coming towards us at 108 km per second, and though it's already near closest approach, 10,000 years from now its proper motion will have sped up to an annual rate of 26 seconds of arc. Unfortunately, Barnard's star is a dim, cool main-sequence dwarf barely detectable in binoculars, and when closest will still be invisible to the naked eye.

But what of times past? Through the southern constellation of Pictor moves a high velocity sub-dwarf, Kapteyn's star. Currently it has the southern celestial hemisphere's largest known proper motion, but 11,000 years ago, when the glaciers were retreating for the last time, Kapteyn's star moved across the sky at nearly 30 seconds of arc per year. Its rapid motion went unseen, however, because even then its feeble light lay below human perception.

700,000 years ago a modest second magnitude star may have gone unnoticed by the eyes of early Man. Today this star, known obscurely as Gliese 894.3, is a tenth magnitude object in Aquarius. Though surely visible, primitive Man had no way of knowing this star was only ¾ of a light-year away, and therefore perhaps the closest star in Earth's recent history! Flashing by less than 50,000 astronomical units away, Gliese 894.3 would probably have had profound effects on the Sun's comet swarm. Perturbed from their placid, chilly existence, they would then begin the long fall to the Sun, eventually swinging around it and heading on out again to the edge of the solar system.

It's a shame that some of the most impressive lights in the heavens blazed out before the arrival of Homo Sapiens. In 1,500,000 B.C. did our early Pleistocene ancestors really appreciate the dazzling beauty of Canopus, even now the second brightest star? The enormous luminosity of this white-hot supergiant may have made it a rival of Venus' -4 magnitude brilliance, although it never came closer than 20 light-years.

Not surprisingly, the past also anticipates the future, except that more comprehending and appreciative eyes will be watching. In 35,000 years, Ross 248, a 12th magnitude star scarcely visible in a small telescope, will brighten to 10th magnitude as it drifts 20 seconds of arc per year across the sky, passing at a distance of 3 light-years. And if our species survives another million and a half years, we might see Venus again outshone. This time Gamma Scuti, a whitish star similar in type to Sirius, may have come within 3 light-years, from where it'll sparkle at a magnitude of -5.

Do any of the stars appear to have courses which would make them both bright and *really* close? Disappointingly perhaps not, yet one candidate might just do that: BD +61° 366. This rather unprepossessing object hides among other 7th magnitude stars only a few degrees from Epsilon Cassiopeiae. Its observed proper motion is very small and uncertain, suggesting that it is far away. However, it's been classified as a red dwarf, a type of star somewhat cooler and smaller than the Sun. While the spectral classification is tentative, if it *is* correct, then BD +61° 366 should be only about 30 light-years distant. (Spectral classification gives indications of how bright a star really is, which leads to a distance estimate when the star's apparent brightness is known.)

Taken at face value, these figures lead to extraordinary results when combined with its modest approach rate of 12 km per second. During the next 800,000 years this star may well brighten by 10 or 11 magnitudes as it moves slowly from Cassiopeia over the celestial pole, past the bowl of the Little Dipper, and then rapidly down into Bootes, where shining at four times the brilliance of Sirius, it'll speed past the stellar background at 30 seconds of arc every year. If humans still populate

Do-It-Yourself Encounter Predictions

The calculations behind this article may appear formidable, but in fact they can be done on a simple pocket calculator. To do it yourself, all you need is one that takes square roots and gives $\log_{10}$ of a number. Such machines are about as common as salt these days, so why not give it a try?

The only math involved concerns a right triangle, where the hypotenuse represents the star's present distance, and the distance at closest approach stands for one leg of the triangle. You *are* assuming that the star's velocity remains constant, but so long as you restrict the time span to about 1% of the Sun's galactic period of revolution (which works out to 2.5 million years), you should be all right. This also coincidentally spans the time humankind has been evolving.

Required data are: the star's present distance, its proper motion, and its radial velocity. These three quantities, plus its apparent brightness, will suffice to derive the minimum approach distance, proper motion at minimum approach, the apparent magnitude then, and finally the time interval between now and the moment of closest approach.

OK, now where are you to dig out the data? Several lists of nearby stars exist which tabulate the necessary numbers. Unfortunately, most or all of them can be found only in university or large public libraries. (They are listed below at the end of this box and in the box on page 13.)

When you do start searching out stars, you'll soon find that most naked-eye ones are distant, while the nearby stars are dim, usually visible only with a telescope. This runs a bit counter to what you might expect, but there's no arguing with nature.

When you have the data you need, you start in with each case using the following six equations. It's best to work through them in sequence, since the result of one equation becomes a necessary ingredient of the next.

Here goes!

1) **Tangential velocity = 4.74 x P.M. x Dist.**

where the symbols mean:

P.M. = proper motion (in seconds of arc per year)

Dist. = distance in parsecs (to get parsecs, divide light-years by 3.26)

Your answer for tangential velocity will be in kilometers per second.

2) **Space velocity^2 = T.V.^{2} + R.V.^{2}**

where:

T.V. = tangential velocity

R.V. = radial velocity

Remember that all figures must be in equal units — kilometers per second. To work this equation, square the values for T.V. and R.V., then add them and take the square root of the result. This gives the space velocity.

3) **Minimum distance = 4.74 x Dist.^{2} x P.M./S.V.**

where the units are as in the preceding equations. The answer will be in parsecs; convert to light-years as shown before with equation 1.

4) **New proper motion = (0.0444 x S.V.^{2})/(Dist.^{2} x P.M.)**

where units are as before. The result is in seconds of arc per year.

5) **New magnitude = Mag. + (5 x log [Min. dist])**

where:

Mag. = apparent magnitude at present

Min. dist. = minumum distance in parsecs

The answer, of course, will be in magnitudes.

6) **Time = 979,000 x Dist. x R.V./S.V.^{2}**

where units are as before (distance in parsecs), and the result is in years.

Have fun!

Sources

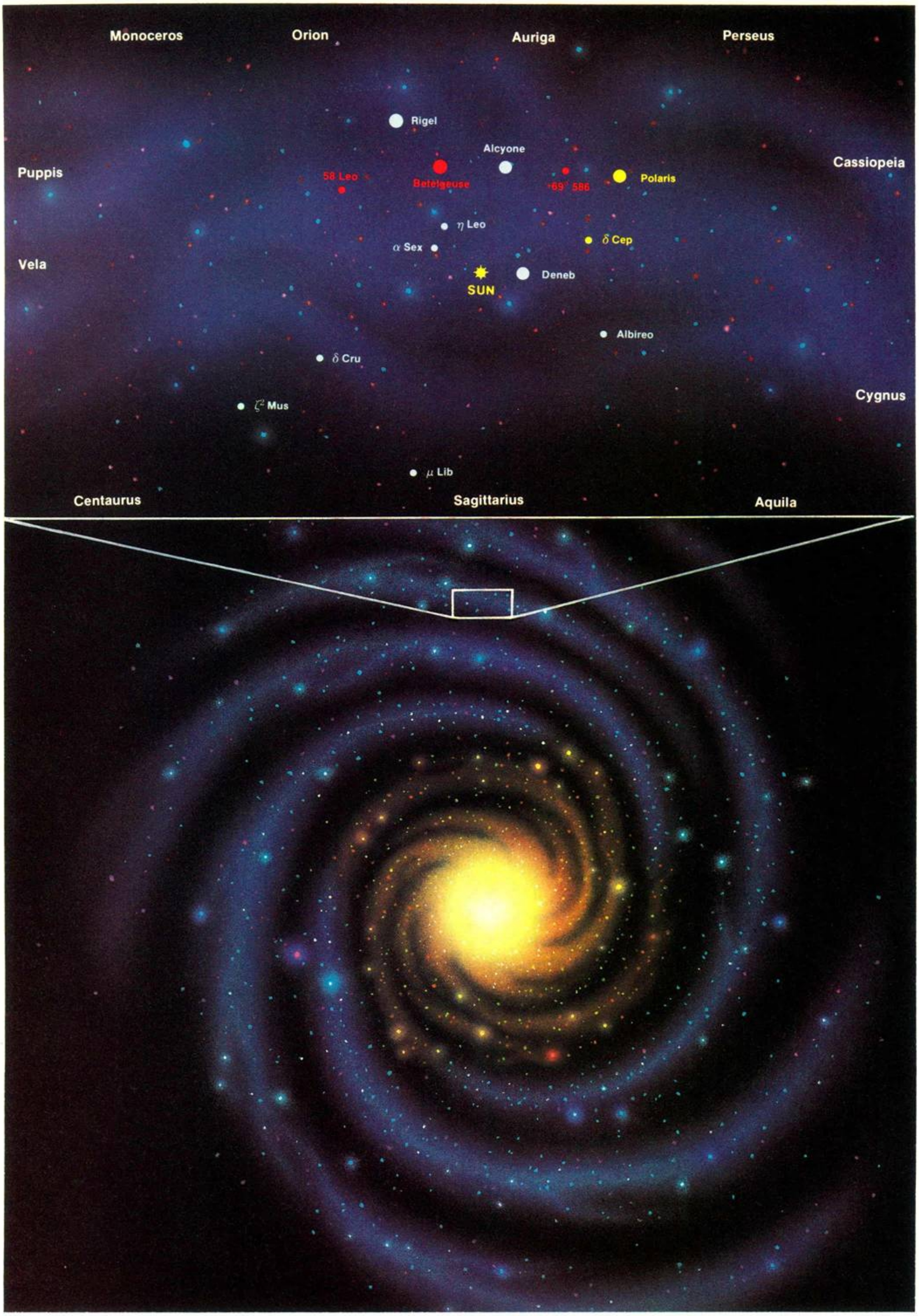
C.W. Allen, **Astrophysical Quantities**, 3rd ed., 1973 (Athlone Press, London)

P. van de Kamp in: **Annual Review of Astronomy and Astrophysics**, volume 9, page 103, 1971 (Annual Reviews, Palo Alto, CA)

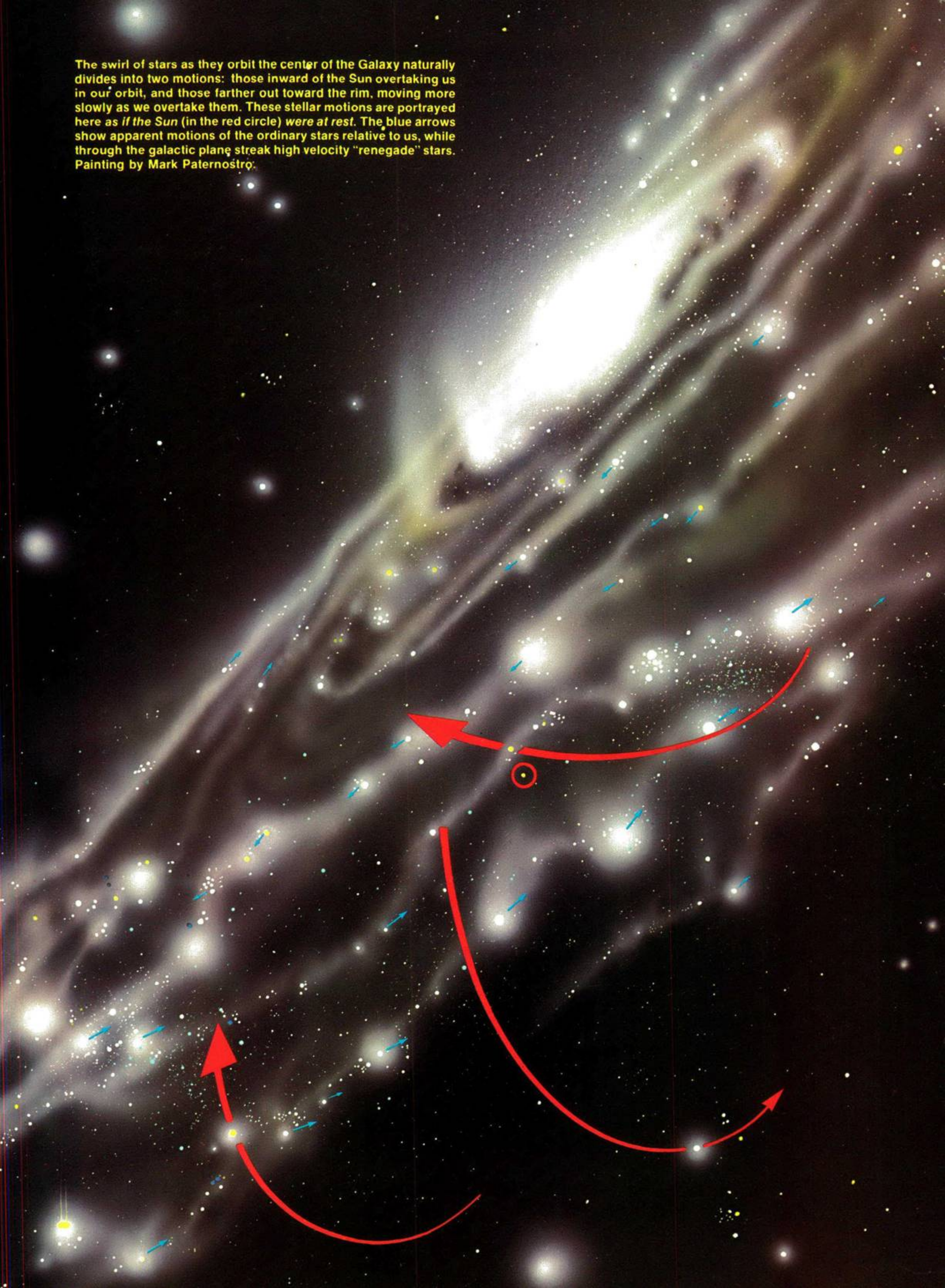
W. Gliese, **Catalog of Nearby Stars**, Veroeffentlichungen, #23, 1969 (Astronomisches Rechen-Institut, Heidelberg)

D. Hoffleit, **Catalog of Bright Stars**, 3rd revised ed., 1964 (Yale University Observatory, New Haven)

Our Galaxy and the Sun's neighborhood: In the upper box you see several stars in the vicinity of the Sun and their positions relative to us projected onto the plane of the Galaxy. The viewpoint is the galactic north pole. Stars hotter than the Sun appear bluish-white, while those cooler are in red; solar temperature stars are *yellow*. Around the box's edge are the names of Milky Way constellations, and the directions in which we see them. Painting by Thomas Schroeder.


Monoceros
Orion
Auriga
Perseus
Rigel
Alcyone
Puppis
58 Leo
Betelgeuse
+69° 586
Polaris
Cassiopeia
η Leo
α Sex
δ Cep
Vela
SUN
Deneb
Albireo
δ Cru
ζ² Mus
Cygnus
μ Lib
Centaurus
Sagittarius
Aquila

The swirl of stars as they orbit the center of the Galaxy naturally divides into two motions: those inward of the Sun overtaking us in our orbit, and those farther out toward the rim, moving more slowly as we overtake them. These stellar motions are portrayed here *as if the Sun* (in the red circle) *were at rest*. The blue arrows show apparent motions of the ordinary stars relative to us, while through the galactic plane streak high velocity "renegade" stars. Painting by Mark Paternostro.



The 25 Closest Star Systems

Tabulated here are the 25 stellar systems nearest the Sun which are known to astronomers today. A glance over the list tells you that these aren't ordinary stars. For one thing, most don't have the familiar Greek letter designations of Bayer, nor the simple numbers of Flamsteed. The reason is that the majority of these are faint stars, many telescopic, and no one bothered to put letters or numbers to them until astronomers started compiling catalogs of nearby systems. The arcane designations then are abbreviations taken from a particular catalog. Screwy-looking as they are, they soon become as familiar as any other star name.

In the table, the first column gives the star's designation, using the most commonly known and recognizable name. The position columns are self-explanatory (though note that the epoch is 1980). The next column gives the parallax, or annual displacement, of the star (relative to distant objects) in seconds of arc, due to Earth's motion around the Sun. When you see a parallax figure, you can convert to distance very easily. Simply divide 1 by the parallax, and the result is the star's distance in a unit called a *parsec*; each parsec is equal to 3.262 light-years.

Proper motion is listed in the next column, with the units being seconds of arc per year. R.V. stands for radial velocity, which is given in kilometers per second. A positive radial velocity means the star is moving away from us; a negative one signals approach. Mag. is the star's apparent visual magnitude, and it's clear that most of the close stars aren't very bright.

The spectral type is given in the last column, and this tells you the star's place in the stellar temperature scale. The classes run as follows: O, B, A, F, G, K, and M in order of descending temperature. Each class is divided into 10 subclasses, which is why you see F5, G2, M6, K0, etc. (In the cases of Sirius and Procyon, one of the double star components is a white dwarf, hence the "wd" designation.) The Sun is class G2; note, also, how many of the local stars are cooler than the Sun.

Star	R.A.(1980)Dec.				Par.	P.M.	R.V.	Mag.	S.T.
	h	m	°						
α Cen C	14	28	-62	36	0.764	3.841	-15.7	11.05	M5
" AB	14	38	-60	46	.743	3.673	-27.0	-0.29	G2.K0
Barnard's	17	56	+04	36	.553	10.278	-110.0	9.54	M5
W 359	10	56	+07	10	.428	4.691	-12.0	13.53	M8
+36°2147	11	03	+36	07	.402	4.780	--	7.50	M2
Sirius AB	6	44	-16	42	.374	1.323	-7.6	-1.46	A1.wdA
L 726-8 AB	1	37	-18	04	.370	3.318	+29.0	12.50	M5.M5
Ross 154	18	49	-23	50	.345	0.720	--	10.60	M5
Ross 248	23	40	+44	04	.314	1.584	-81.0	12.29	M6
ε Eri	3	32	-09	32	.304	0.980	--	3.73	K2
L 789-6	22	38	-15	28	.298	3.270	-60.0	12.18	M6
Ross 128	11	47	+00	58	.300	1.369	-13.0	11.10	M5
61 Cyg AB	21	06	+38	38	.292	5.204	-64.0	4.80	K5.K7
ε Ind	22	30	-56	52	.285	4.694	-39.0	4.68	K8
σ 2398 AB	18	42	+59	36	.285	2.279	0.0	8.47	M4.M5
Procyon AB	7	39	+05	17	.283	1.248	-3.2	0.37	F5.wdF
+43°44 AB	0	18	+43	54	.280	2.858	+20.0	8.00	M1.M6
G51-15	8	29	+26	51	.278	1.260	--	14.81	--
-36°15693	23	05	-35	59	.273	6.908	+10.0	7.36	M2
+5°1668	7	27	+05	27	.266	3.721	+26.0	9.82	M4
τ Ceti	1	43	-16	03	.263	1.918	-16.2	3.50	G8
L 725-32	1	11	-17	06	.261	1.358	+28.0	11.60	M5
-39°14192	21	16	-38	58	.255	3.468	+21.0	6.67	M0
Krug 60 AB	22	27	+57	36	.254	0.860	--	9.60	M3.M5
Kapteyn's	5	11	-44	59	.250	8.709	+244.0	8.81	M0

The data in the table have been gathered from a list by Alan Batten in the 1979 **Observer's Handbook** of the Royal Astronomical Society of Canada and a recent paper in the **Astrophysical Journal Supplement Series** (v. 39, p. 89-101, 1979) by Olin Eggen.

the Earth in 800,000 A.D., they could watch this exquisite, golden star drift the full angular diameter of the Moon in a single lifetime. Epochs might be reckoned by its changing position and legends may arise about this mysterious, wandering star.

If the dwarf classification of this star is correct, BD +61° 366 ought to be incredibly close in future times: only a quarter of a light-year (15,000 astronomical units) away. Its gravitational effects on the Sun's comet cloud would be terrific, though its influence on Earth's motions would still be inconsequential.

However, it's very possible that more accurate information about this star would substantially alter these conclusions. In fact, its color (if reliably determined) makes it much too red for most dwarfs. Instead this star may well be a faraway, red giant and no longer a candidate for such a remarkable encounter. Moreover, its small proper motion will likely have large errors. But if you're one of those bewitched by doomsday prophecies of colliding worlds, remember that errors can be either plus or minus. It remains plausible that BD +61° 366 intrinsically is a much cooler and redder (therefore dimmer) dwarf than we think, in which case it could approach the very limits of the solar system. In any event, serendipity has led us to an interesting, but little known star.

Clearly the results of this little excursion are of no immediate consequence. What is notable is that astronomy continues to be an important and useful part of our culture because it constantly presses us to view our lives and actions within a framework of some larger meaning. For those who know some astronomy, the inspirational qualities of the heavens can be awesome.

Howard Cohen and John Oliver are associate professors at the University of Florida. Their professional interests concern close binary star systems, while this article arose from a desire to present basic astronomy in a new and compelling way.

JPL/NASA photograph 1-15

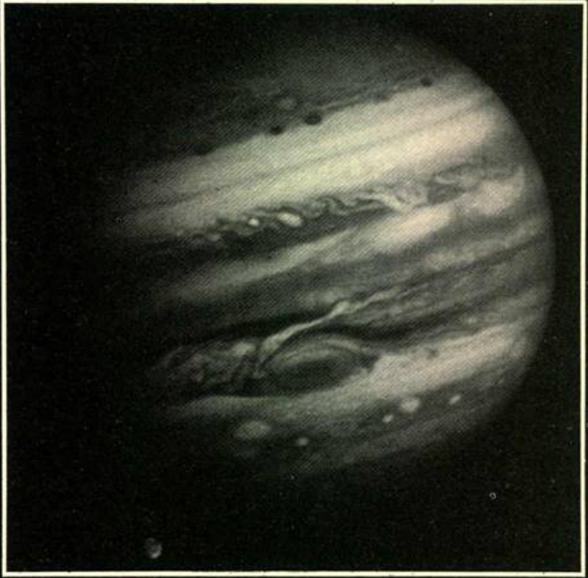
Voyager Approaches Jupiter

"The best is yet to come!" said ebullient JPL/NASA scientists, pleased to nearly solid superlatives by the performance of the Voyager 1 Jupiter spacecraft drawing toward Jupiter at some 700,000 miles per day. As this issue of ASTRONOMY goes to press, NASA plans call for Voyager to return well over ten thousand photographs during the Jupiter encounter — pretty pictures admittedly, but also hard scientific data on the circulation of the jovian atmosphere, detailed surface geology of the four largest satellites, and a search for new satellites. One intensive observation period involved continuous monitoring of the planet for four days — resulting in 3600 detailed pictures of the ever-changing cloud belts.

Much attention was focused on the Great Red Spot, an atmospheric feature seen on Jupiter almost since the telescope was first invented. During the days leading up to encounter, the Red Spot was too large to fit in a single camera frame, so mission scientists took mosaics of pictures to splice together into composite pictures of the Spot. Activity long suspected, but never seen clearly before, has been found: the Spot is churning in a counterclockwise direction. One complete rotation takes about six days. Compare the picture on the opposite page (taken January 29 at a range of 22 million miles) to the one on the cover. During the five days between these pictures, the yellowish feature has completed about 5/6 of a turn. Other features are changing too, particularly the region just to the left of the Red Spot.

Jupiter's other swirling cloud belts are changing rapidly, too. The black and white photographs are blue-light versions of the cover picture and the picture opposite. In them, you can compare jovian cloud patterns yourself, detail by detail.

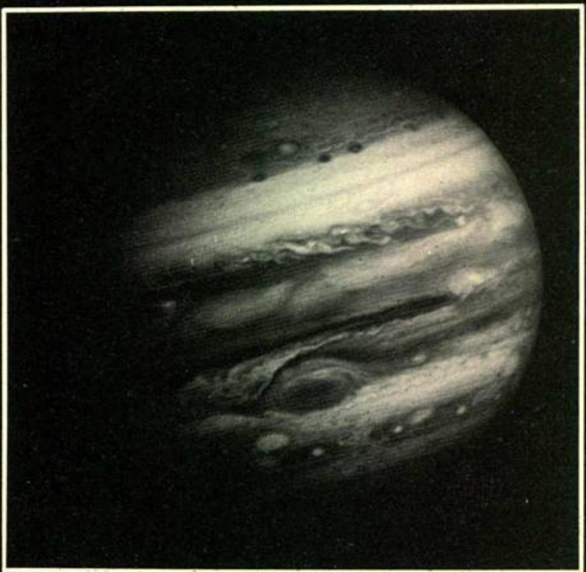
As this issue of ASTRONOMY goes to press, nearly two weeks remain before Jupiter fly-by. If all goes well with the mission, the May issue of ASTRONOMY will bring you a complete report on the mission.



JPL/NASA photograph 1-10

Jupiter: January 24, 1979

Jupiter: January 29, 1979



JPL/NASA photograph 1-16

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>
> Your full aperture Solar Skreen & Cell and the Binocular Eyepiece that I ordered for my Celestron 8 arrived at the same time as a belated monsoon. However, yesterday cleared dramatically and I was able to use both for the first time on the sun. The result was a revelation — I realised that I've never really seen the sun before. I was quite stunned by the detail I could see inside of the sun-spots and faculi and above all the detail in the granulation covering the entire disc. I could scarcely believe my eyes; there was no comparison with my beloved QUESTAR — though this is quite unfair because I only have a one-inch filter for it.
>
> I can see why people think you are kidding when they unpack the SOLAR SKREEN as I must say it is not very good to look at but I can't believe that any degradation of the image occurs when it is used on the sun. I do imagine that a full aperture optical filter will cost many hundreds of dollars and I very much doubt if it would give any better views. I am really delighted with it, and it has turned me on to the sun!
>
> That same evening I had stunning views of the five day old Moon with the STEREOOCULAR. Again I would like to record my delight with these two accessories on my CELESTRON 8. You can quote this letter any way you wish.
>
> Regards,
>
> Arthur C. Clarke

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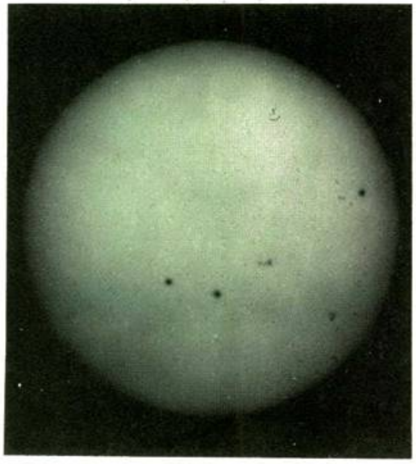

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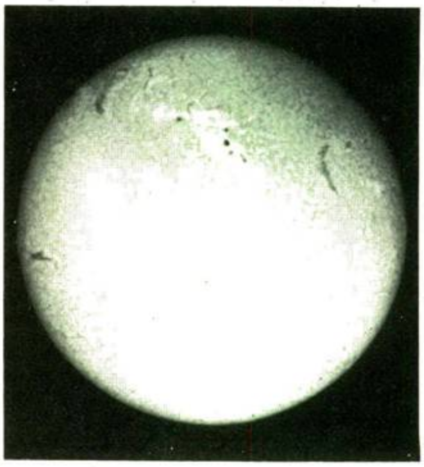

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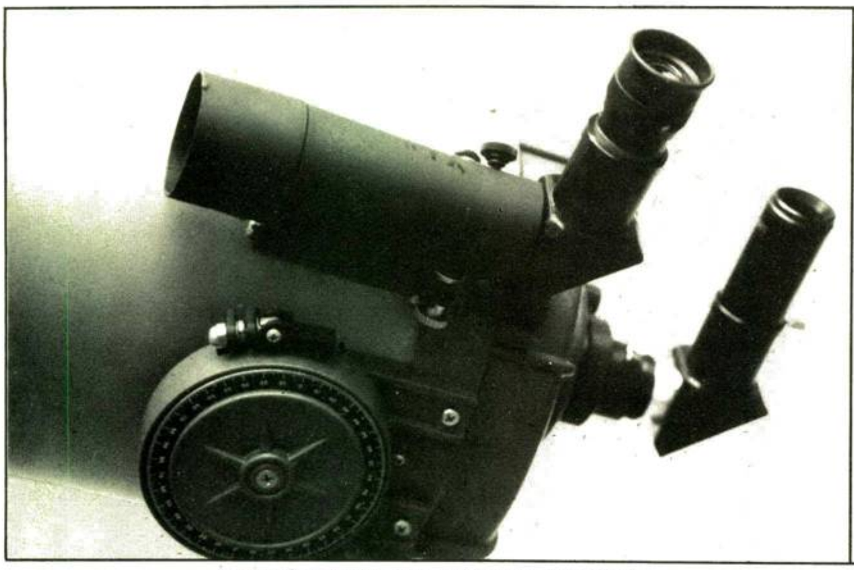

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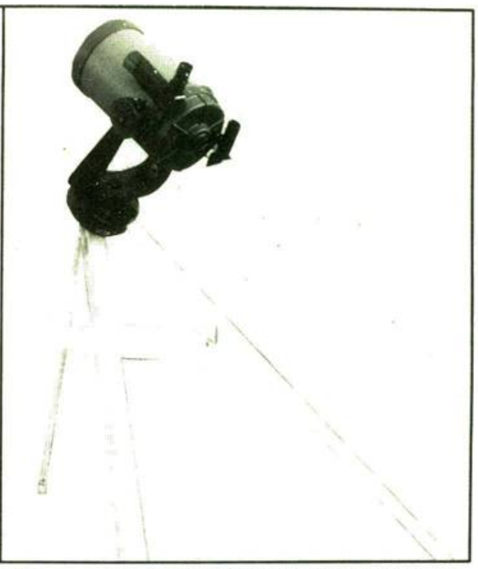

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Pioneer Venus: First Results

NASA scientists have announced the first batch of findings coming from the recent Pioneer probes to Earth's sister planet, Venus. It includes new information on the formation of the inner planets, an explanation for the heat which creates Venus' hell-like surface environment, and observation of "mysterious chemical fires" on the planet's surface.

The five atmospheric probes which comprised Pioneer Venus 2 entered the planet's atmosphere on December 9, 1978. All the data returned at that time has now been reduced, and analysis has already produced a number of significant results. Pioneer Venus 1, an observing station, began an eight-month mission on December 5, 1978, when it entered its elongated orbit about the cloud-covered planet.

Pioneer found several hundred times more primordial argon and neon on Venus than on Earth. (Mars, on the other hand, has far smaller amounts of these two primordial gases than Earth.) The argon-neon findings challenge currently accepted theories of solar system formation. Most of them propose that the Sun and planets formed at about the same time, with the planets forming from a gas cloud surrounding the Sun and composed of the same elements as the Sun.

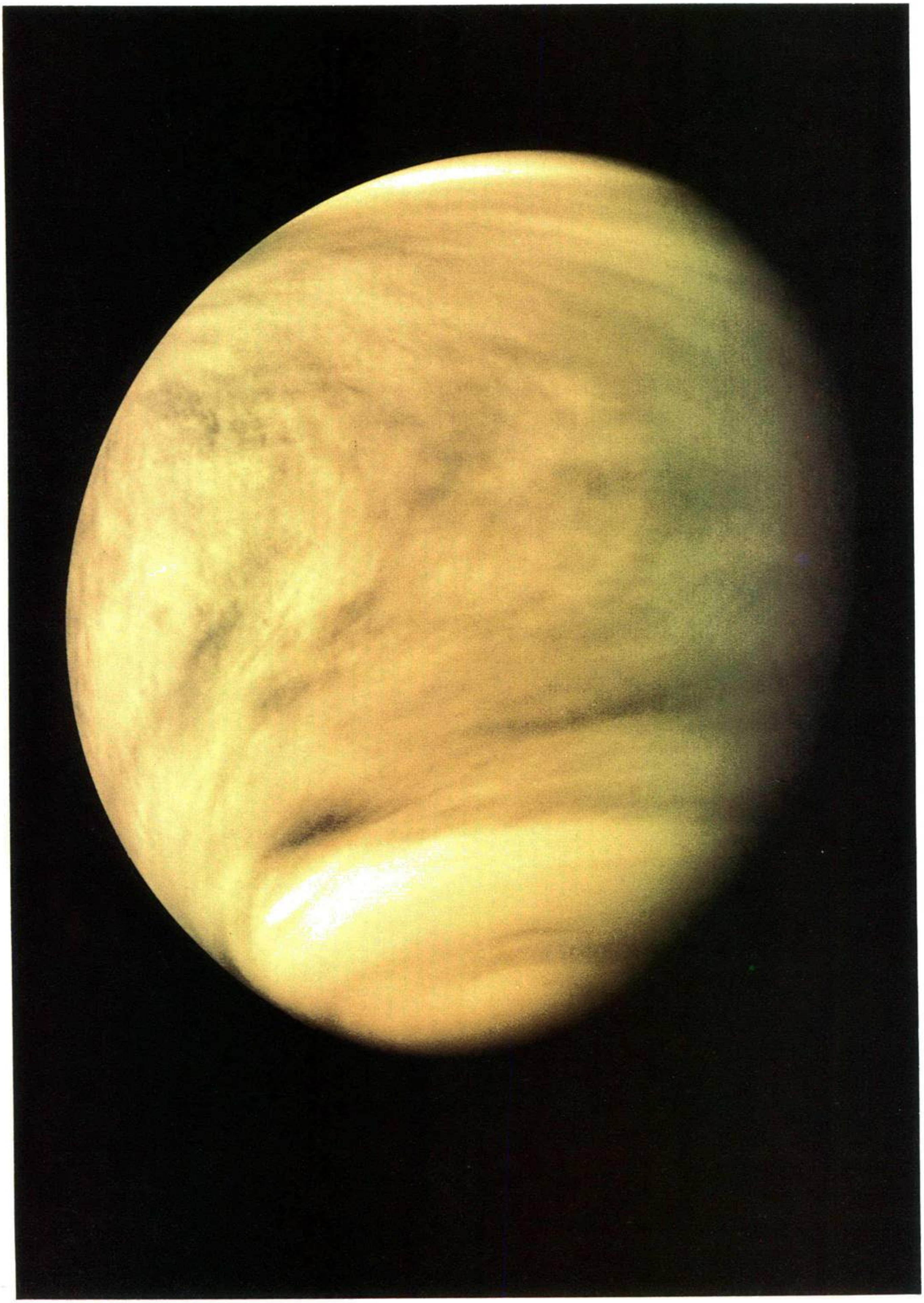
Prior to Pioneer Venus, astronomers generally thought that the light elements, including argon and neon, present in the atmospheres of Mars, Earth, and Venus, had originally escaped (degassed) from each planet's interior after its formation. It also was assumed that the original solar gas and dust cloud was hot in the center and much cooler farther out. Thus, at the time when the rare gases were being trapped in the pre-planetary material, the innermost part of the solar system should have been low in these elements. Venus was expected, therefore, to be low in argon and neon. But the Pioneer data showed just the opposite.

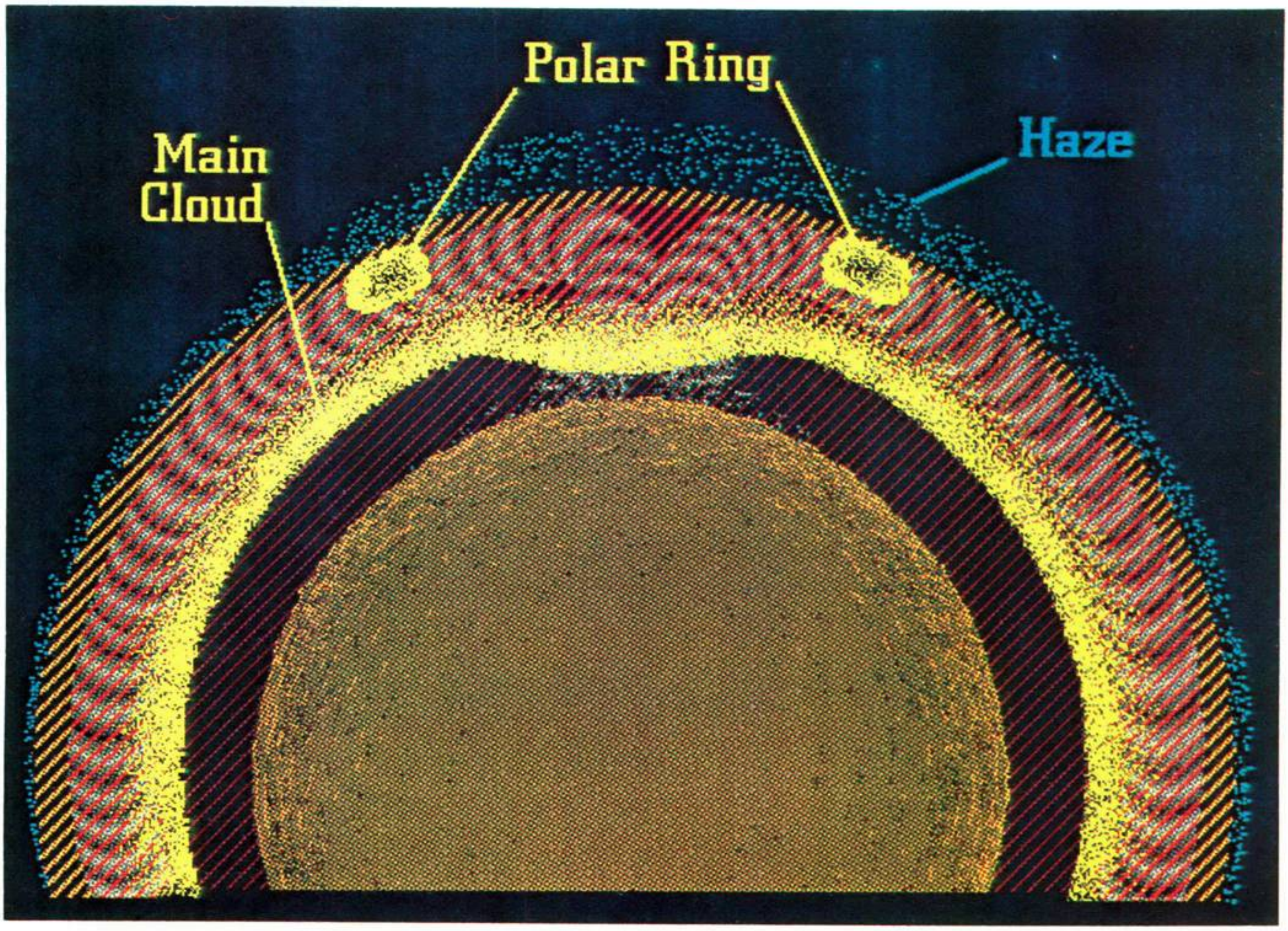
These new results imply that the temperature distribution in the early solar system was different than generally assumed. The fact that neon and argon are found in about the same proportions on Venus and Earth further strengthens the idea of a more uniform process and steady increase in density of all materials going toward the Sun.

Venus' intense heat now seems to be explained by a massive "greenhouse" mechanism rather than by the competing theory of heat circulation from the top of the atmosphere down. Of Venus' total incoming sunlight, about 25% is absorbed in the clouds, atmosphere, and surface. As this absorbed solar energy attempts to leave the surface and atmosphere as heat radiation, two materials, identified by Pioneer Venus, hold the heat in the atmosphere. Until now, the dense (97%) carbon dioxide atmosphere was known to trap much of the heat, but not enough to account for the searing surface temperatures of up to 850° Fahrenheit (455° Celsius). The somewhat surprising finding is that 0.1 to 0.4% water vapor in the atmosphere provides the second very strong heat trap. Finally, it is now believed that the large solid and liquid sulfur particles in the cloud layers contribute to putting a lid on the venusian pressure cooker.

The clouds of Venus themselves, about 12 miles thick, lie in three distinct layers. The top layer is about 9 miles thick, extending down to 35 miles altitude. This layer is (probably) made up of droplets of sulfuric acid at a temperature of about 55° F. The second layer, about 4 miles thick, lies between 35 and 31 miles altitude, and seems to be made up of larger liquid particles in addition to the particles of sulfuric acid — plus even larger particles which could be solid elemental sulfur. Not as dense as the first layer, the second has a temperature of about 68° F. The bottom layer is the only one opaque enough to be like most Earth cloud structures. Only 3 miles thick, it is the densest of the three and lies between 31 and 30 miles altitude. It seems to be composed of large particles of what might be both liquid and solid sulfur with only a few small sulfuric acid particles, and is at a temperature of about 395° F.

This image of Venus was obtained by the Pioneer Venus Orbiter spacecraft on January 18th. Taken from 40,000 miles high and somewhat south of the planet's equator by the spacecraft's cloud photopolarimeter instrument, it shows the brightened polar rings (especially the southern one, visible near the bottom of the picture). The complex pattern of clouds shows belts just north of the equator (above the middle of Venus' image here), numerous bowlike waves in the subpolar region, and convective "cellular activity." The "Y" feature, which shows clearly in the pictures on page 22, is very weak in this picture. Ames Research Center/NASA photograph.





Above: The high, bright, and cold polar cloud ring is shown schematically. The ring appears to be a permanent part of the atmospheric circulation pattern. At the pole, cloud tops seem to be about 6 miles lower, and much warmer than the surrounding cloud tops. A high haze layer (blue) is thicker over the pole and has infrared characteristics that show it may contain water vapor or ice as Earth's cirrus clouds do. Right: This picture was taken four days before the picture on page 19. Although it is superficially similar, look carefully and you'll see many differences. Ames Research Center/NASA photographs.

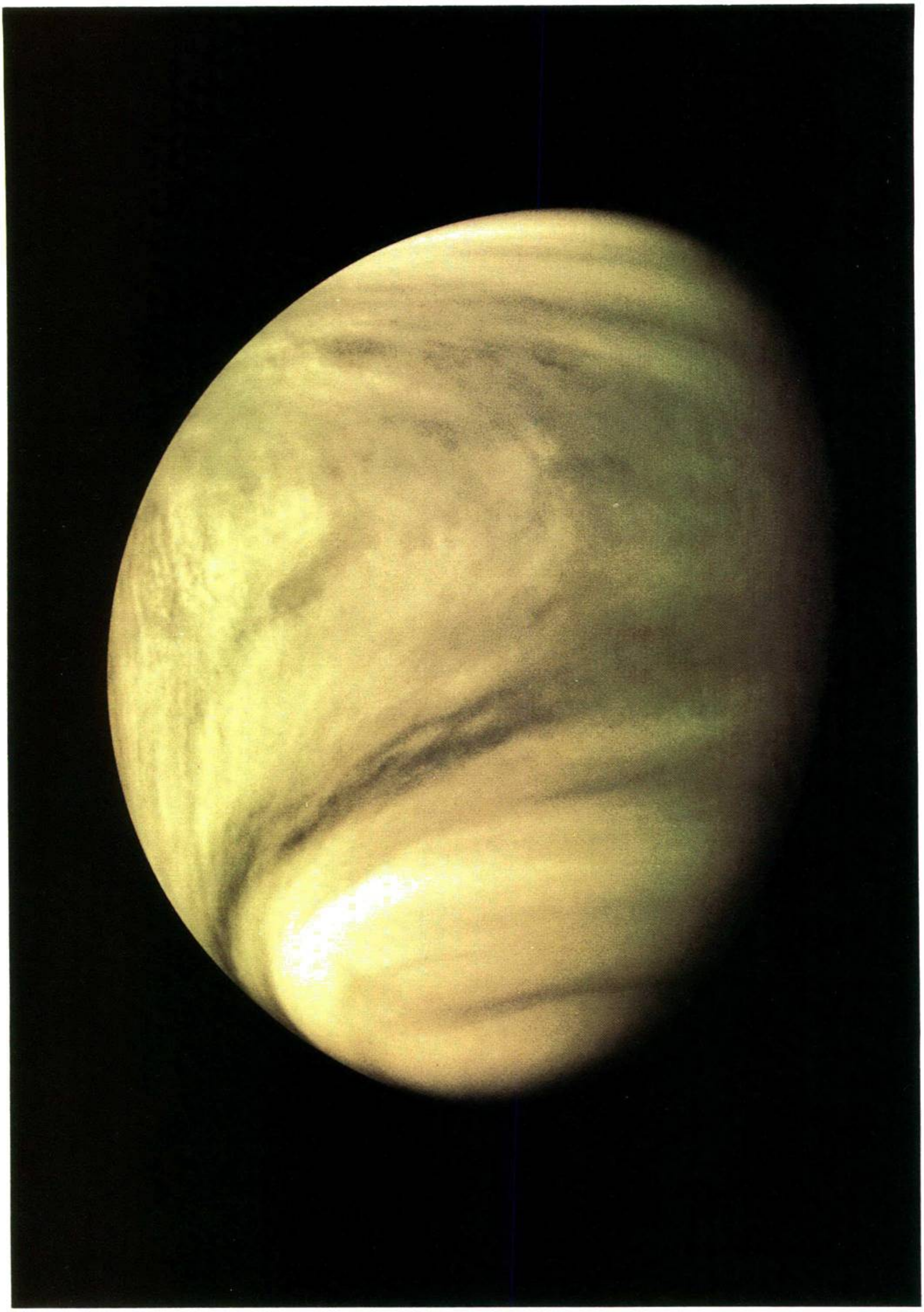
Below the bottom cloud layer, where the temperature reaches the melting point of sulfur, a haze of what might be tiny particles of sulfuric acid gradually thins out over the next ten miles until, at an altitude of about 19 miles, the atmosphere becomes free of particles. This "clear air" extends down to the surface. The dark markings, visible in images of the planet from the orbiter, are believed to be due to elemental sulfur in the cloud layers. A "cyclic rain" of sulfuric acid was also seen, in which droplets condensed out of the vapor to fall through the atmosphere to a layer of higher temperature, where they were then vaporized again.

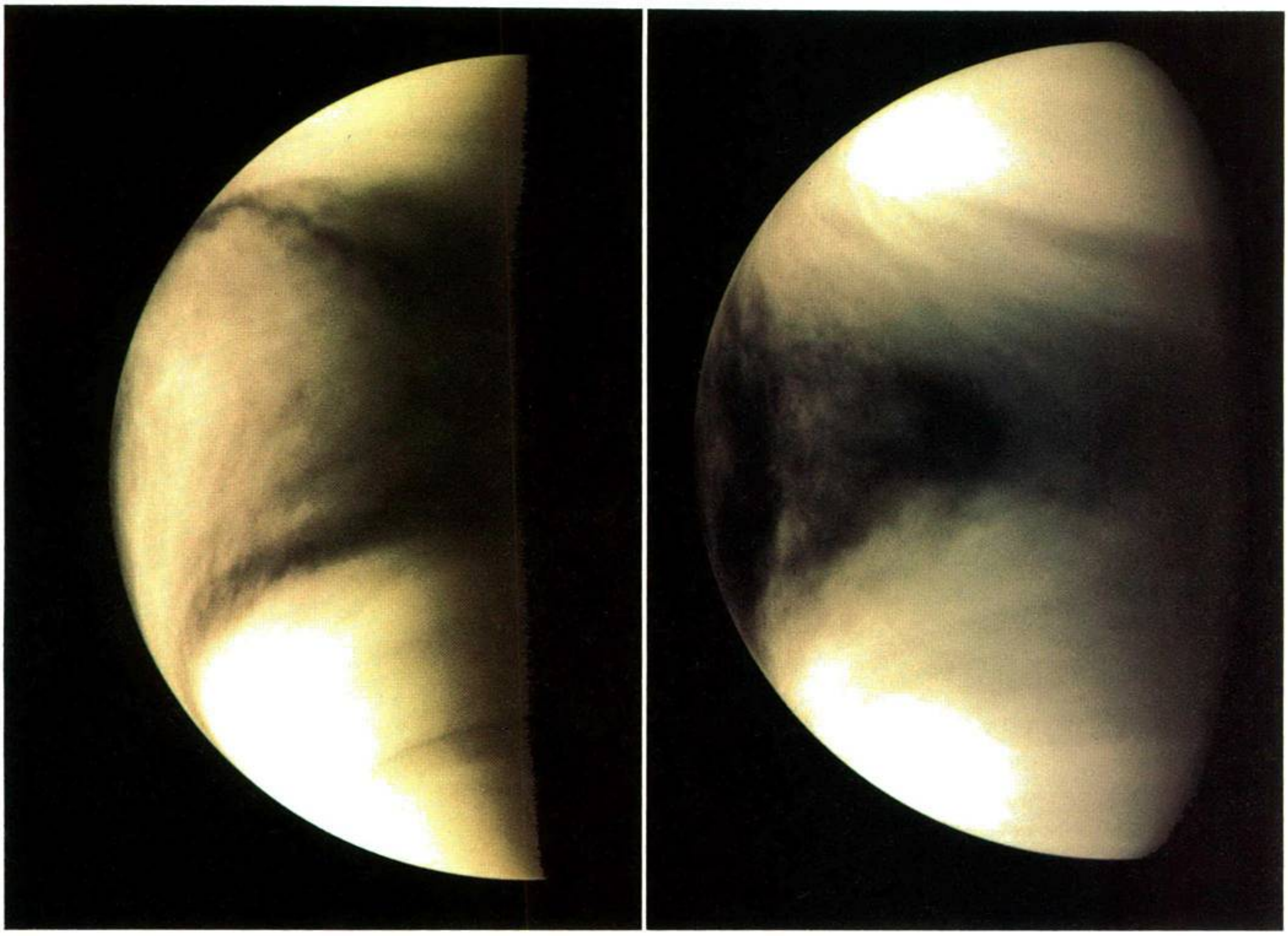
Radar scans of the surface suggest plate tectonic activity, which is known to take place on Earth, but whether such activity is current or is a relic of long-ceased activity, however, is not known. The radar shows a large rift valley at 18°-19° south latitude, 165° longitude, extending 150 to 180 miles across the surface. The overall shape of Venus was also determined via radar studies: we now know Venus is about ten times less oblate (flattened) than either Earth or Mars. In general, the surface seems remarkably similar to Earth's, with high mountainlike features and extensive, relatively flat areas.

The Pioneer Day Probe showed the presence of fine dust on the surface at its landing site in the southern hemisphere. This dust took about three minutes to settle after impact of the 200 pound probe which struck the surface at 22 miles per hour.

One of the most mysterious observations was made by the two nightside probes. Starting at an altitude of 8 miles, an unexpected glow was detected, which increased as the probes descended. Mass spectrometer evidence for various sulfur compounds near the surface suggests that the mysterious glow could come from "chemical fires" on the surface or in the very hot, dense lower atmosphere near the surface. The "fires" could be fueled by reactions involving the sulfur compounds. Experimenters are also considering another possibility: that the glow resulted from the heated or electrically charged surfaces of the probe craft themselves.

Meanwhile the Orbiter has found a wide ring of colder and higher clouds that circles the poles at about 70°. In the "polar hole," believed to be created by this ring, cloud tops seem several miles lower





The dark "Y" feature is shown clearly in these pictures taken December 25 (left) and December 30 (right) by Pioneer Venus Orbiter's photopolarimeter. The "arms" of the "Y" show up in the images at left, while the "trunk" is best seen in the image at right. The "Y" is present, but very weak, in the pictures on pages 19 and 21. Plainly visible in both pictures are the polar rings, which appear about 50% brighter now than they did in 1974 during the Mariner 10 flyby. The polar ring shows a number of appendages that stick out at odd angles. Ames Research Center/NASA photographs.

than the surrounding ones. A polar hole was definitely observed over the north pole, and one is believed to be present over the south pole as well.

Another orbital experiment shows that the solar wind interacts with the venusian atmosphere several times more strongly than scientists expected. Unlike solar wind interaction on Earth (which has a magnetic field), three key upper atmospheric regions of Venus were discovered to almost coincide. These are the *turbopause* (where atmospheric mixing begins), the region of maximum ion density, and the base of the *exosphere* (the region where gases escape the planet into space).

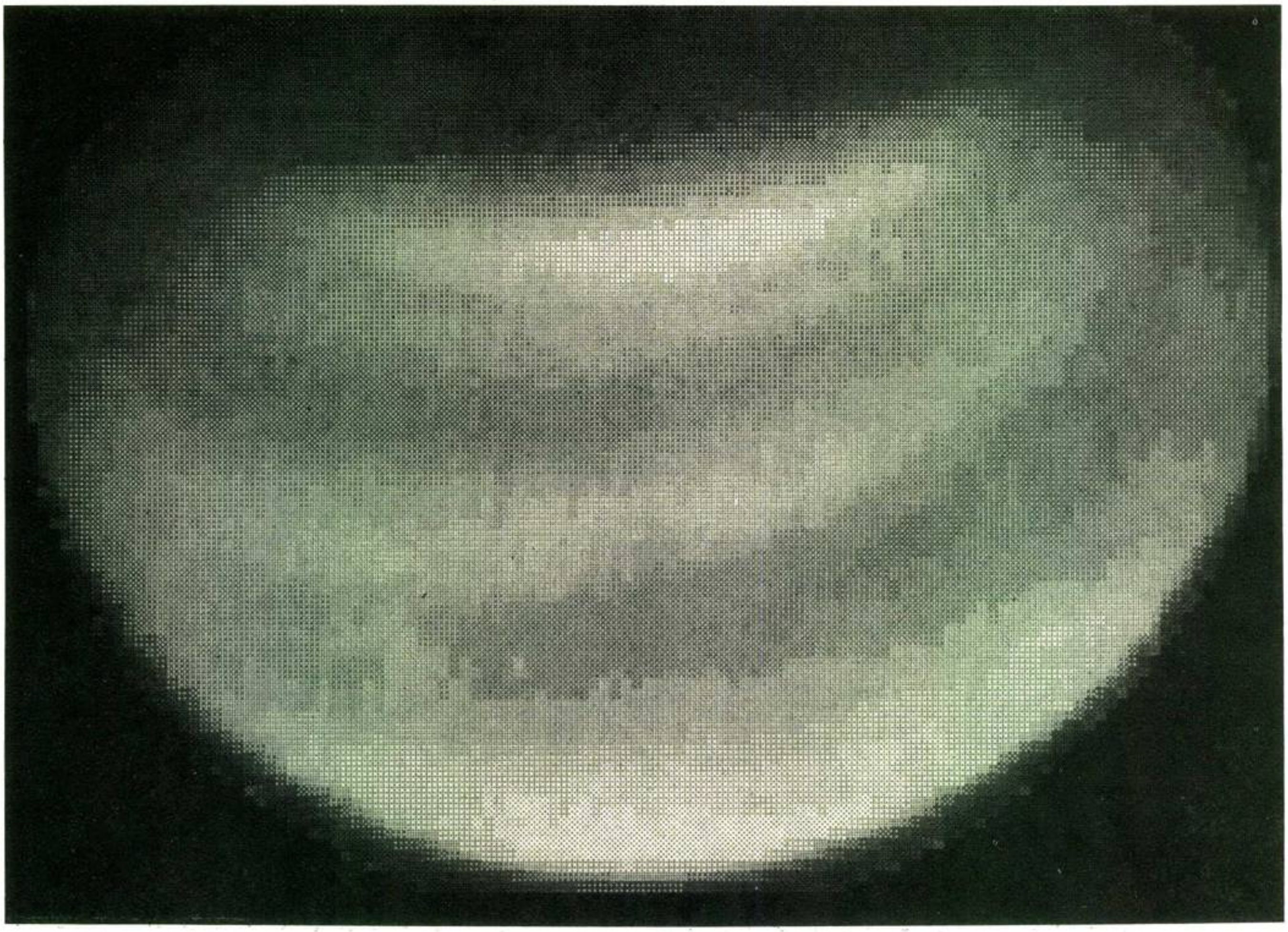
A Revised, Updated, Imaginary Trip to Venus' Surface

What would it be like to travel to Venus on board your own spaceship? Thanks to Pioneer Venus, we can now say — with reasonable confidence — what such an experience would be like.

Gliding toward the brilliant, yellowish, cloud-covered planet outside your spaceship's window, your instruments would register the bow shock wave in the solar wind about 4,650 miles from the venusian surface. Reaching the top of the ionosphere at about 240 miles altitude, you pass through a turbulent transition region. As a passenger, all you'd notice would be the first slight braking forces. Then, as your spacecraft begins its descent through the tenuous upper atmosphere, toward the yellowish sulfurous clouds far below, the gee-forces begin to build. As your ship passes the turbopause at 90 miles, the clouds begin to resolve into a dense, smoglike haze.

The Sun begins to grow dim at about 41 miles from the surface, after you enter the first of the cloud layers. By the time an altitude of 39 miles is reached, the Sun is no longer a visible disk behind the diffuse yellow cloud layer. These clouds, made up of tiny sulfuric acid particles, cut visibility through the high venusian smog at that height to about 4 miles. The temperature has risen to 55° F, and the atmospheric pressure is already half that at Earth's surface. Atmospheric drag is so great that your fall is almost a glide. The gee-forces drop off nearly as quickly as they began.

At an altitude of 31 miles, in a comfortable outside temperature of 68° F, you would see only



This ultraviolet picture of Venus was made by the ultraviolet spectrometer aboard Pioneer Venus Orbiter on January 31. This image, looking down toward the pole, is cut off at the top near the north pole; bright pole-circling clouds can be seen near the top of the picture as well as near the extreme lower edge (those clouds circle the southern pole). The darker areas coincide with regions of high sulfur dioxide concentration. These views suggest that Venus' dark markings are due to holes in the high cloud deck allowing views down to the lower sulfur dioxide bearing clouds. Sulfur dioxide is one of the materials from which sulfuric acid is formed. Ames Research Center/NASA photograph.

about one mile beyond your ship's windows. After passing a short, clear space in the hazy cloud layers (a truly dramatic vista with clouds both above and below you), your ship falls into the bottom cloud layer. The atmospheric pressure is about equal to that on Earth's surface, but the temperature has suddenly risen to 395° F. The sulfur clouds are densest here, and look rather like cloud structures on Earth. But despite superficial resemblances, you know they are made up of sulfur and sulfuric acid.

Beneath the dense sulfur cloud, your lander falls quickly through a second clear space and then a "pre-cloud" layer only a few hundred yards thick. A faint haze outside your window gradually clears as your ship drops to an altitude of 19 miles.

Gradually the atmosphere becomes clear of particles. Horizontal visibility in the diffuse light coming through the yellowish clouds is 50 miles — in fact you notice that the illumination is strikingly similar to a bright cloudy day back on Earth. But the temperature just outside your window is now 590° F.

Below, you can see only a reddish murk, and it doesn't look very appealing.

Starting at about 12 miles altitude, where the temperature is 716° F, the light becomes redder. Visibility drops to around 12 miles. Six miles above the surface, the light is very red, and horizontal visibility is only 7 miles. The illumination has become quite dim and gloomy, and as you watch the outside thermometer rise to 770° F, you remember the reputation of Venus as the "hell-planet."

When you're only about four miles above the surface, you begin to see some surface features — for the first time — gleaming through the red murk below you. As you descend, they become more and more distinct, but you can no longer tell where the Sun is located in the sky. Only about 10% of the Sun's light is reaching the ground, and as your ship settles down on a dusty, barren landscape, the light is a dark, dim red. The dense atmosphere causes a great deal of refraction and distortion of the rocks strewn about on the ground. Only the longest red wavelengths can travel any distance through this atmosphere composed mostly of carbon dioxide — 91 times as dense as the atmosphere at the Earth's surface. Visibility in the dense air is only a mile and a half. Outside, the temperature is 850° F. Perhaps you now wonder why you are here at all!

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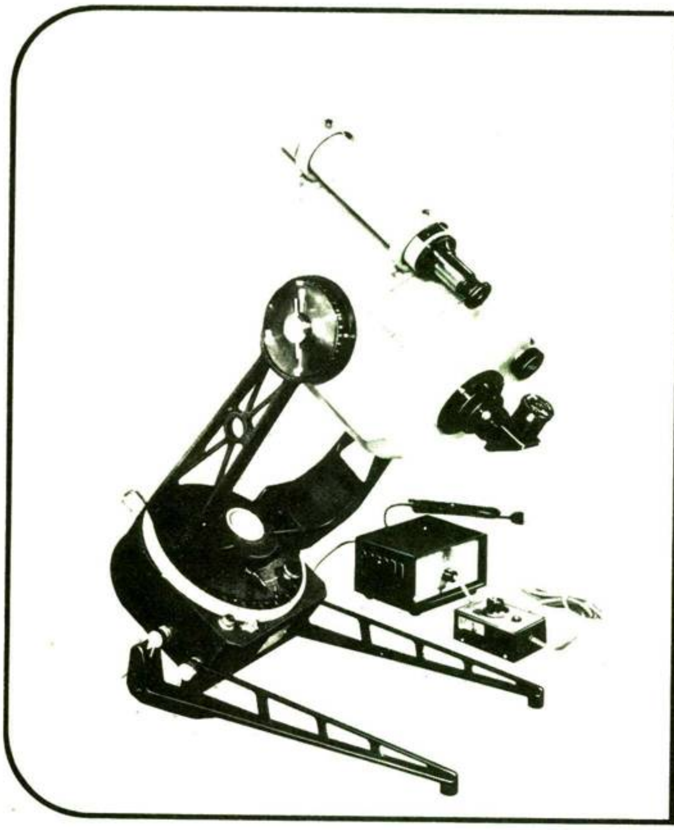

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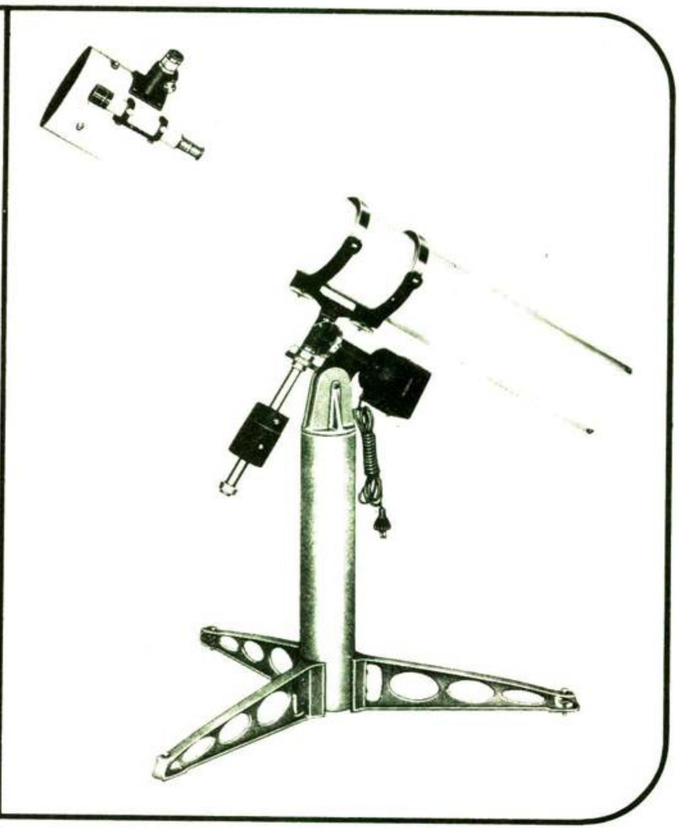

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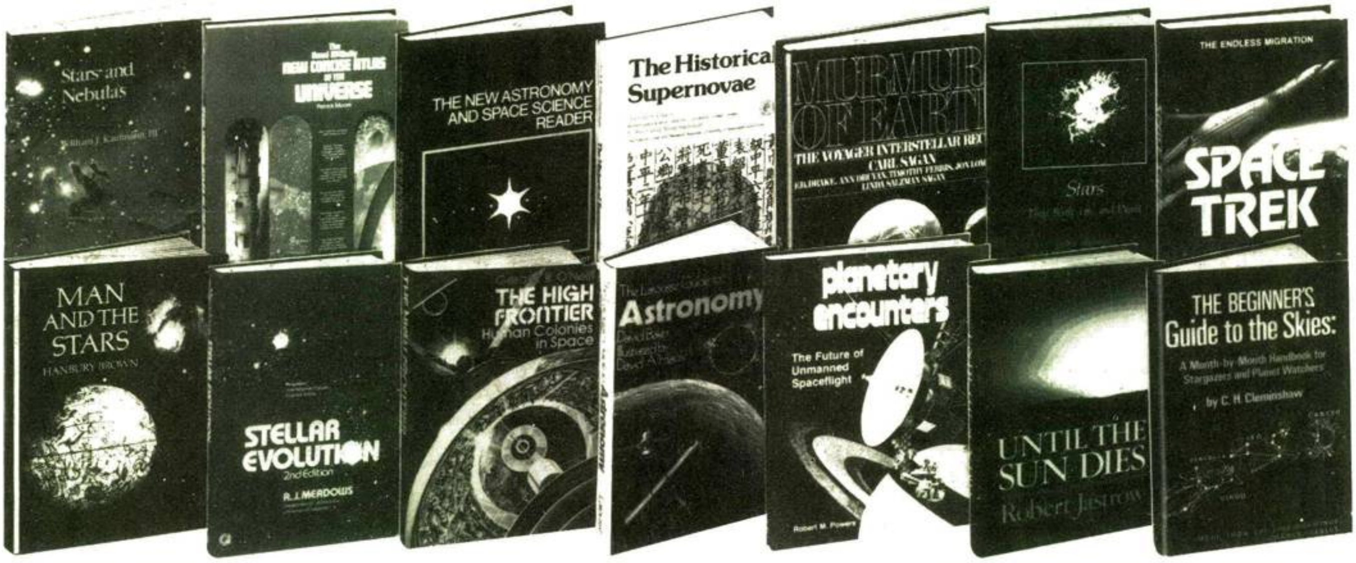
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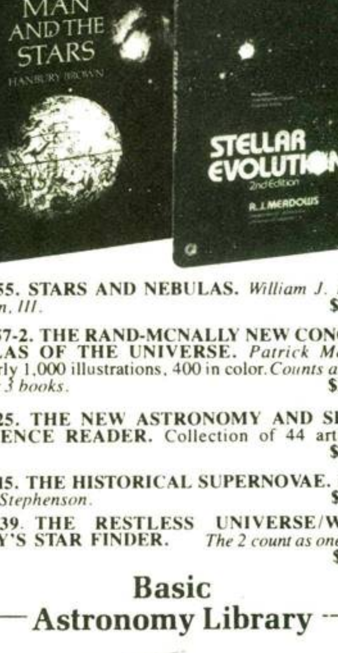
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SKY ALMANAC

Conjunction in the Dawn

April's most unusual event comes during the last week of the month when the Moon will conjunct with Venus and, a day later, occult Mercury. Try not to miss it! Most of the planets are easily seen at one time or another during the night, and there's a little meteor shower to whet your interest. So get out there and take advantage of the warmer nights.

Mercury

Having passed between us and the Sun on the 24th of last month, Mercury is now moving out to the west of the Sun, reaching greatest elongation from it on the 21st. On this date, the little planet will be 27° west of the Sun, but due to its southerly declination, you won't see it get very high above your southeastern horizon. This elongation is an *aphelic* one, meaning that Mercury is nearly at its maximum orbital distance from the Sun. The elongation could be a very good one if it weren't for the orbital coincidence that puts Mercury at a southern declination when it's farthest from the Sun, thus "wasting" these elongations for mid-northern latitudes.

On the morning of April 2nd, Mercury will be passing just to the north of Mars, immediately before sunrise. Both planets will be about equally bright (Mercury: +1.9; Mars: +1.4) and very low in the southeast.

On the morning of the 24th, the Moon, two days before new, will occult Mercury for observers to the east of the Rockies. This event will be harder to see than the spectacular Venus occultation last December because all the events happen either during twilight or after sunrise. For the eastern United States and Canada, the disappearance and reappearance both occur after sunrise. The middle part of the continent sees the disappearance before sunrise (and reappearance after), while those just to the east of the Rockies miss out on the disappearance (since it comes before moonrise), but do get to see the reappearance before sunrise.

Mercury will be 7.5 seconds of arc in diameter, at magnitude +0.5, and just barely more than half the visible disk will be lit. Venus at the time will be about 7° to the upper right, shining at magnitude -3.4. Binoculars will show the event well, but you'll need a telescope to discern Mercury's phase. The occultation and conjunction will be very pretty, so don't miss them if you can help it.

Venus

Venus continues its bright appearance in the morning sky, though it's dipping ever closer to the horizon, while sliding steadily northward to follow the Sun. An altitude-azimuth diagram of Venus' motions is on page 29, where the path it'll take relative to the horizon is plotted from now through the end of July, when it dips too close to the Sun to be easily seen.

If you follow the planet through a telescope over the coming months, you'll observe a featureless white disk that becomes constantly rounder while growing smaller and a bit dimmer. During April, the planet's phase will increase from 77% lit to 85%, while its angular size will shrink from 14 seconds of arc to 12.2. Over the same time span, the brightness will slip only a tenth of a magnitude: -3.5 to -3.4.

The Moon comes relatively close to Venus on the morning of the 23rd, when it'll be to the upper right of the planet, and of course on the morning of the 24th, when Mercury will be occulted.

Moon

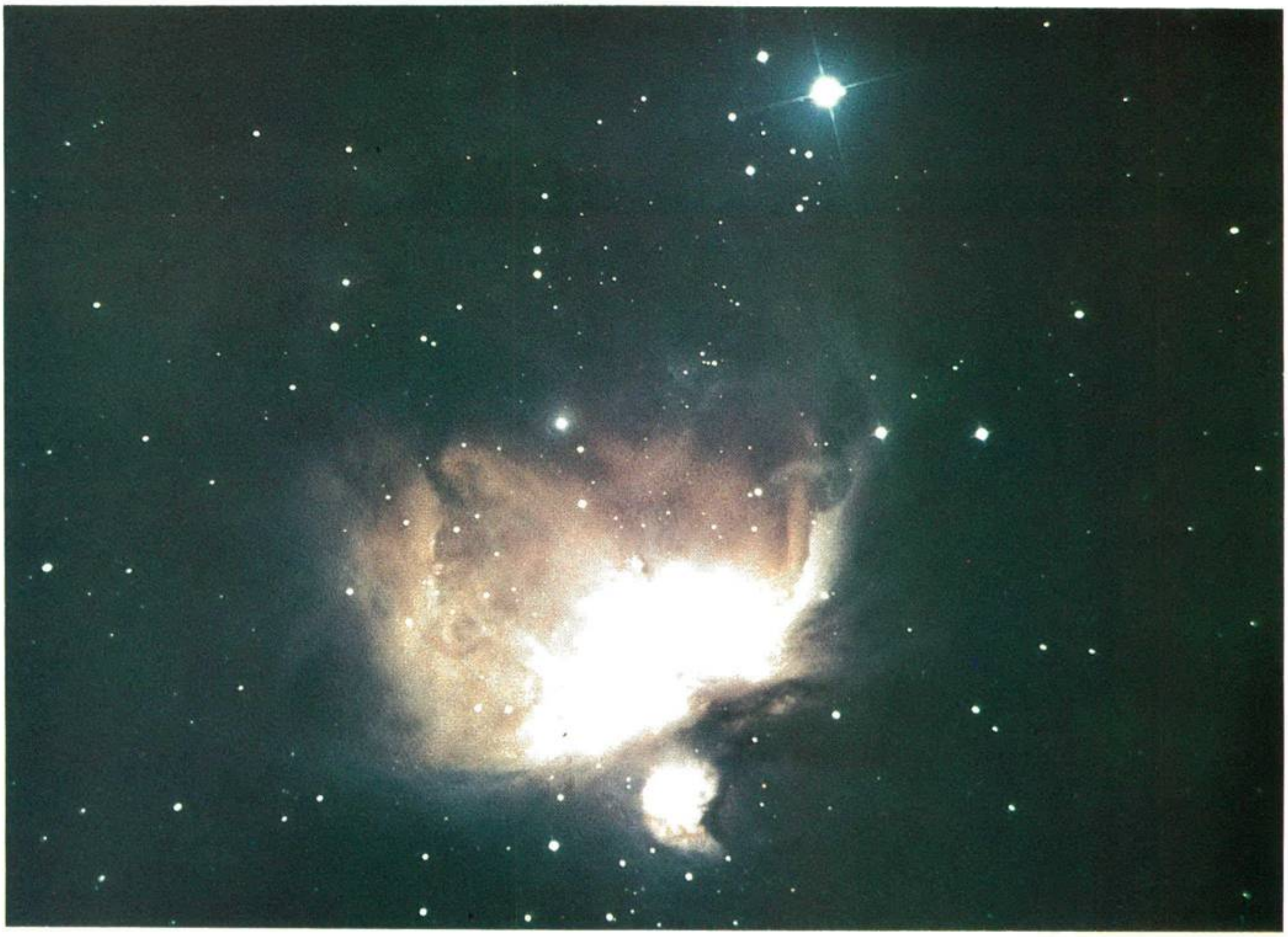
On the evening of the 28th, a waxing crescent Moon passing through the Hyades cluster will occult Aldebaran as seen from the western four-fifths of the continent. Roughly speaking, watchers to the west of the Mississippi will catch both the disappearance and reappearance; those east of there will

Photo Tips!

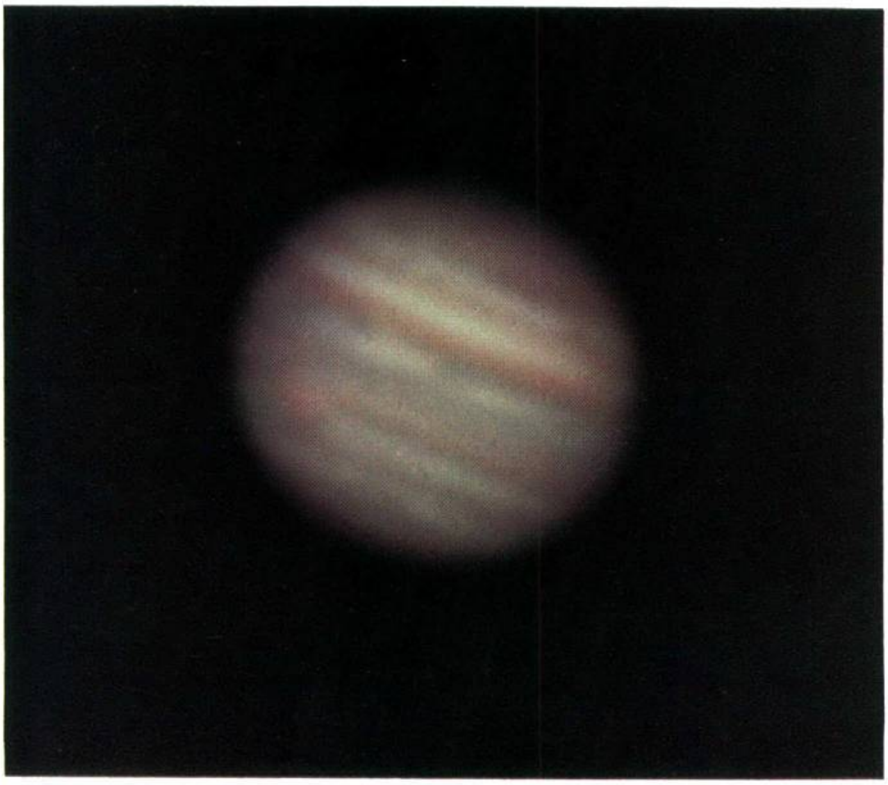
If you're planning to send us one or more of your latest photos, here are a few tips to remember:

1. Please send prints or slides only, no negatives!
2. Don't send silk-surfaced or textured papers — we can only use glossy.
3. Print your name and address on *each* item sent!
4. Send us only your best ones!

Above: Coronal streamers burst out in Aries and Andromeda during the September 29, 1978 auroral display. This photo was made with a seven second exposure at f/1.8 on ASA 400 slide film push-processed to E.I. 800. The lens had an 85 mm focal length. Below: A few minutes earlier, this scene was recorded in the east. Veiling Orion, the aurora shows some relatively rare pink color, indicating intense energies. The photographic data are the same as in the photo above, except the exposure was 10 seconds. Photographs by Don Carney.



That glorious flower in the sword of Orion, M-42, spreads its glowing tendrils in this photo by Jack Newton (above). He used Ektachrome 400 slide film with his 12½ inch, f/4.5 reflector, for a 35 minute exposure. Below: Don Primi used a 14-inch Schmidt-Cassegrain at f/33, for 1½ seconds to record Jupiter onto ASA 64 slide film.



see only the disappearance before moonset happens.

First quarter: April 4th, at 9^h57^m UT, in Gemini. Full moon: April 12th, at 13^h15^m UT, in Virgo. Last quarter: April 19th, at 18^h30^m UT, in Sagittarius-Capricornus. New moon: April 26th, at 13^h15^m UT, in Cetus.

Mars

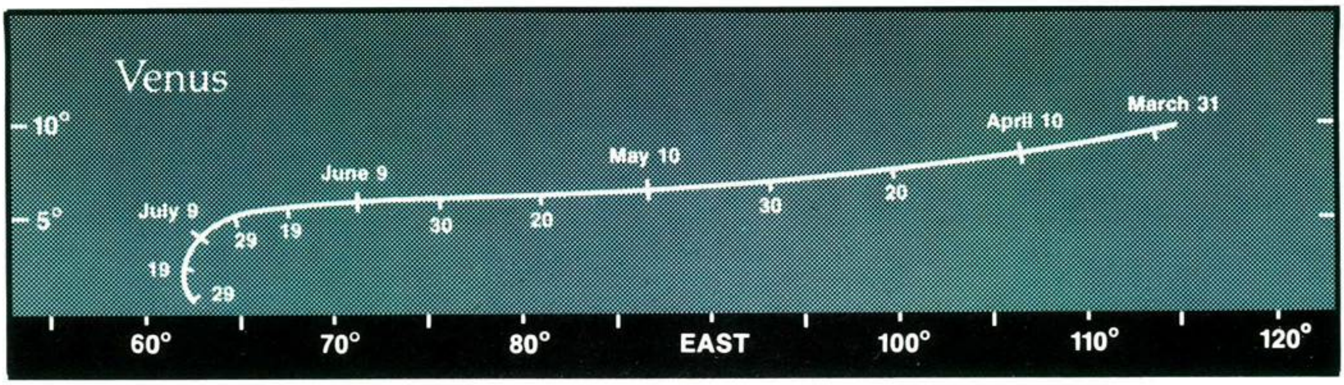
Mars will be slowly drawing higher and higher in the southeastern sky each morning, but several months must pass before there's much to see. Try watching for it (and Mercury, just to the upper left) on the morning of the 2nd. You'll probably find that binoculars are the ideal instrument.

During April, Mars will increase in apparent size by only 0.06 seconds of arc — from 4.04 to 4.1 seconds. Not much! Still, take a look for it with your scope, using whatever powers the unsteady air will allow you. You may be able to make out a few markings on the disk.

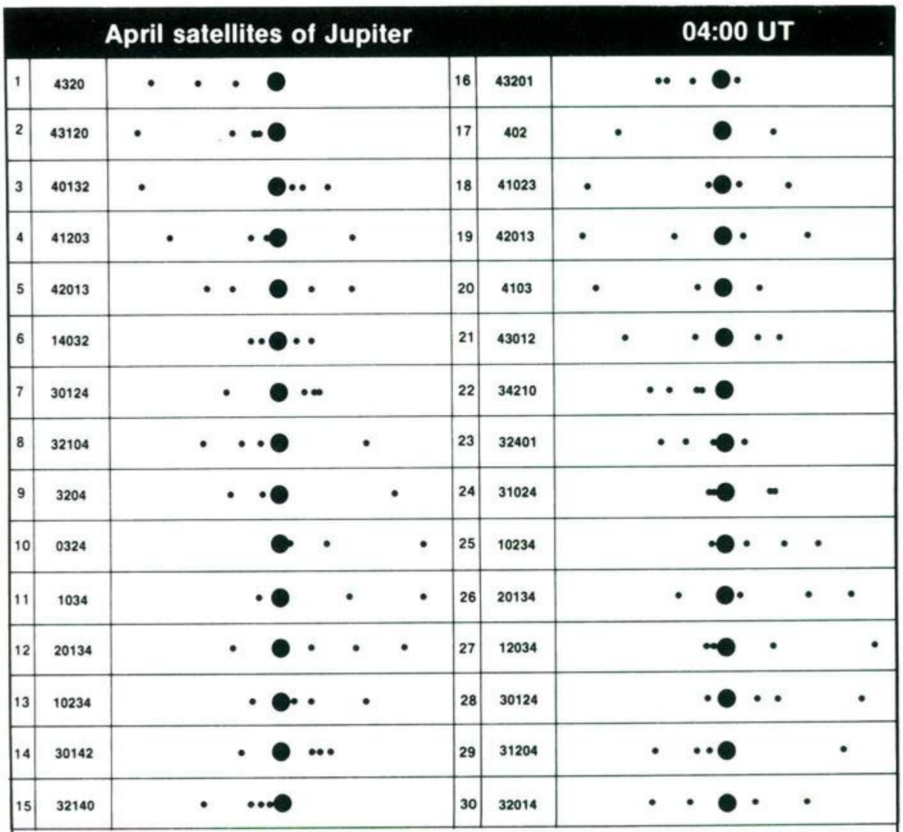
The middle of April corresponds on Mars to the 21st of December on Earth, thus marking the start of the martian northern hemisphere's winter.

Asteroids

Ceres, Pallas, Juno, and Vesta are all now in the morning sky, but still fairly close to the Sun. On the 15th of the month, look for them at the following



The path Venus makes in the dawn sky is shown here from late March until late July, when it gets too close to the horizon. The time is half an hour before sunrise, the latitude is 40° north.



April satellites of Jupiter **04:00 UT**

1	4320	16	43201
2	43120	17	402
3	40132	18	41023
4	41203	19	42013
5	42013	20	4103
6	14032	21	43012
7	30124	22	34210
8	32104	23	32401
9	3204	24	31024
10	0324	25	10234
11	1034	26	20134
12	20134	27	12034
13	10234	28	30124
14	30142	29	31204
15	32140	30	32014

The four major satellites of Jupiter orbit the planet in periods ranging less than 2 days to 17 days. You'll see them change position from night to night. This table shows the approximate position of the moons each night. The column at the far left shows the date; the second column gives the names of the moons (Jupiter = 0, Io = I, Europa = 2, Ganymede = 3, Callisto = 4). The third column shows the satellites' positions as they appear through an inverting telescope; south is at the top.

positions (given in 1950 coordinates to help you plot them on your atlas). Ceres: 23^h 36^m 26.4^s, -11°32′38.4″, at magnitude 8.6, in Aquarius. Pallas: 21^h 10^m 58.9^s, +9°05′26.2″, at magnitude 10.0 in Equuleus. Juno: 0^h 55^m 07.0^s, +2°42′31.1″, at magnitude 9.7, in Cetus. Vesta: 0^h 04^m 45.9^s, -4°39′ 38.7″, at magnitude 8.0, in Pisces.

Jupiter

Jupiter has by now resumed direct (eastward) motion, and is heading back towards the Beehive cluster, which it'll pass to the south of in early June.

Jupiter is dwindling slowly in size and brightness as we move away from it; a fifth of a magnitude is lost over April and the equatorial diameter shrinks from 40.2 to 36.6 seconds of arc.

On the 21st, Jupiter will be at *eastern quadrature*, a term that refers to the time when it is 90° away from the Sun as seen from Earth. Around this time, you may see a very slight phase effect on the disk of Jupiter, where the eastern limb appears slightly less oblate than the western. The actual phase deviation will be only 0.34 seconds of arc from normal, but "limb darkening" on the disk will increase the visible effect somewhat.

Saturn

During this month, the ring system will open up to nearly its greatest extent for this year. (The maximum comes in early May.) As you watch Saturn's brightness over the course of the years, you'll notice how much the rings contribute to its brightness. Right now, just a month past opposition, and with the rings at only a slight angle to the line of sight, the planet appears at about magnitude +0.7, a magnitude fainter than Regulus. But when the rings are seen fully open, the brightness is -0.2 magnitude.

Because the overall light from the planet has become dim, there'll be less glare in your eyepiece if you go hunting for a saturnian satellite. Titan, the brightest of them (magnitude 8.3), will be at western elongation from the planet on the 4th and 20th at 9^h and 7^h UT, respectively. Eastern elongations come on the 12th and 28th at 14.6^h and 12.8^h. At elongation, Titan will be some 4½ ring diameters away from the ball of Saturn.

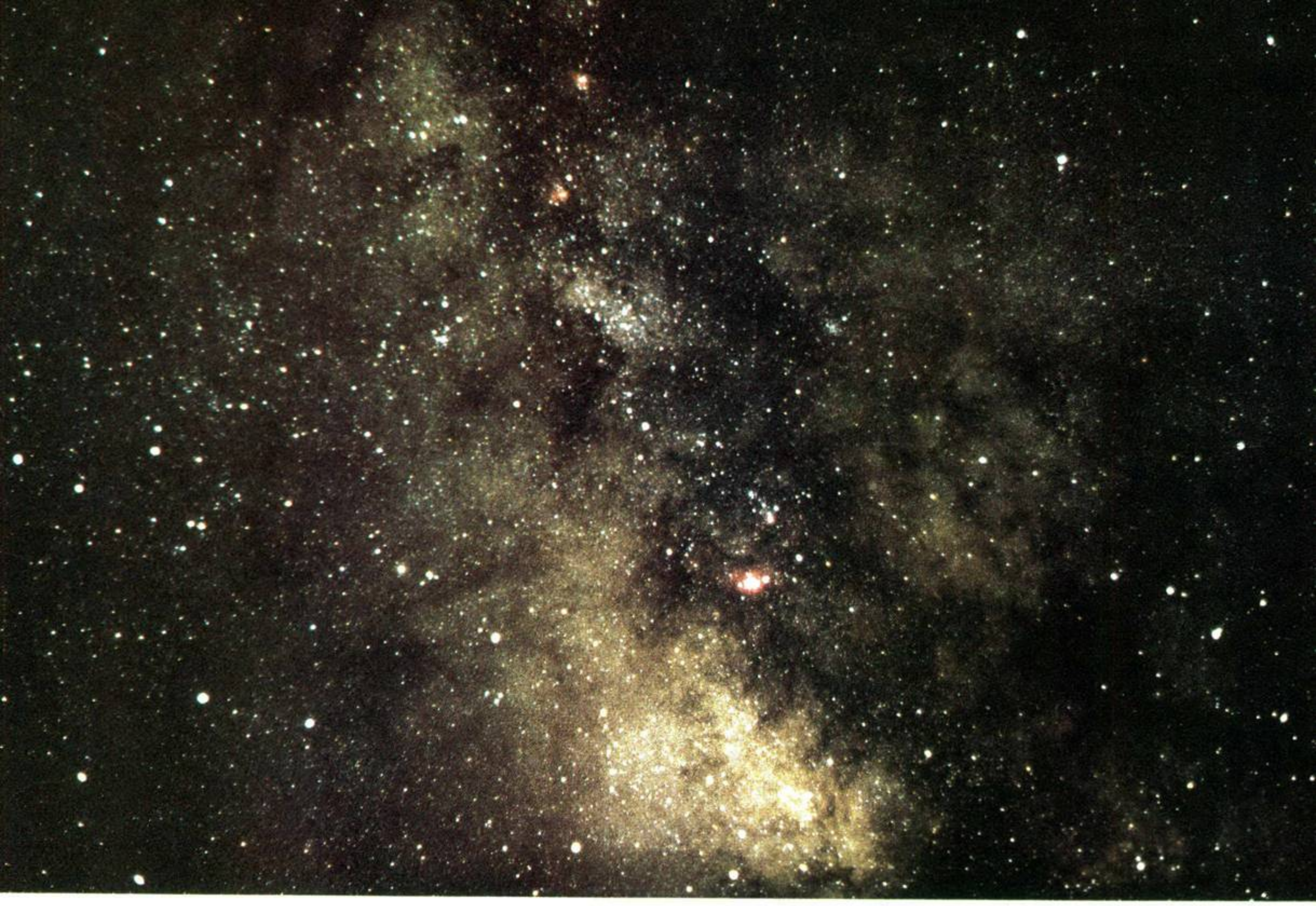
During April, May, and part of June, Saturn will lie about 2° to the southwest of M-95, M-96, and M-105, three 9th magnitude galaxies in the Messier list. Also, on the late evening of the 8th-9th, the Moon will pass 3° to the south of Saturn.

Uranus

Uranus is now retrograding among

Universal Time

Astronomers the world over use an unambiguous system of time reckoning based on a 24 hour clock, called Universal Time (UT). Times given in Sky Almanac are in UT unless noted otherwise. To convert UT into your local standard time, subtract the following number of hours for each time zone: EST, 5; CST, 6; MST, 7; PST, 8; Alaska and Hawaii, 10. For example, if an event is to happen at 03:00 UT on Jan. 2, then the time in EST would be 10 p.m. Jan. 1. Likewise, 03:00 UT on March 5 becomes, in PST, 7 p.m. on March 4.



A preview of things to come! It won't be long before these sights roll into view again. (Even now, you can see them if you take the trouble to be outside around 3 or 4 a.m.) In the center of the photo lie the Scutum-Sagittarius starclouds, with the Lagoon Nebula (M-8) shining redly just below. Photo by Robert Luffel on ASA 200 slide film, using a 50 mm, f/2 lens and exposing for 20 minutes.

Upcoming Events for May

4 First Quarter Moon
5 Mercury 2° south of Mars
Eta Aquarid meteors
6 Saturn 3° north of Moon
10 Saturn stationary in R.A.
Uranus at opposition
12 Full Moon
14 Moon 4° north of Neptune
18 Last Quarter Moon
20 Venus 1½° south of Mars
26 New Moon
29 Mercury at superior conjunction

The month of May offers several conjunctions, as did April. Especially attractive will be the one late in the month, when Venus, Mars, and the Moon will all be within a small part of the southeastern sky, just before sunrise.

The Eta Aquarids are a moderately rich shower that will peak on the morning of the 5th. The radiant point (near the center of Aquarius) rises late, so be prepared if you're going after them. The actual date of maximum seems to be variable, so you could profitably be watching from the beginning of the month onwards. The Moon, praise be, will be near first quarter and out of the sky for meteor watchers.

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the background stars of Libra. Look for it at magnitude 5.8, about 2° to the southeast of 5.3 magnitude Nu (ν) Librae. The planet will have a 3.8 second of arc disk, glowing very pale green.

Neptune

Neptune, for all its tiny disk and dimness, shouldn't be too hard to find. Locate the star Xi (ξ) Ophiuchi (1950 coordinates $17^h\ 18.0^m$ -21°3.7′, magnitude 4.4) in your atlas, and point your telescope at it. Then look less than a degree to the south-southwest to find Neptune. You'll see a disk about 2½ seconds of arc in size and of magnitude 7.7. Learn the region well, for Neptune will be staying in the vicinity of Xi Oph for the rest of the year, giving you a great opportunity to follow its motion easily.

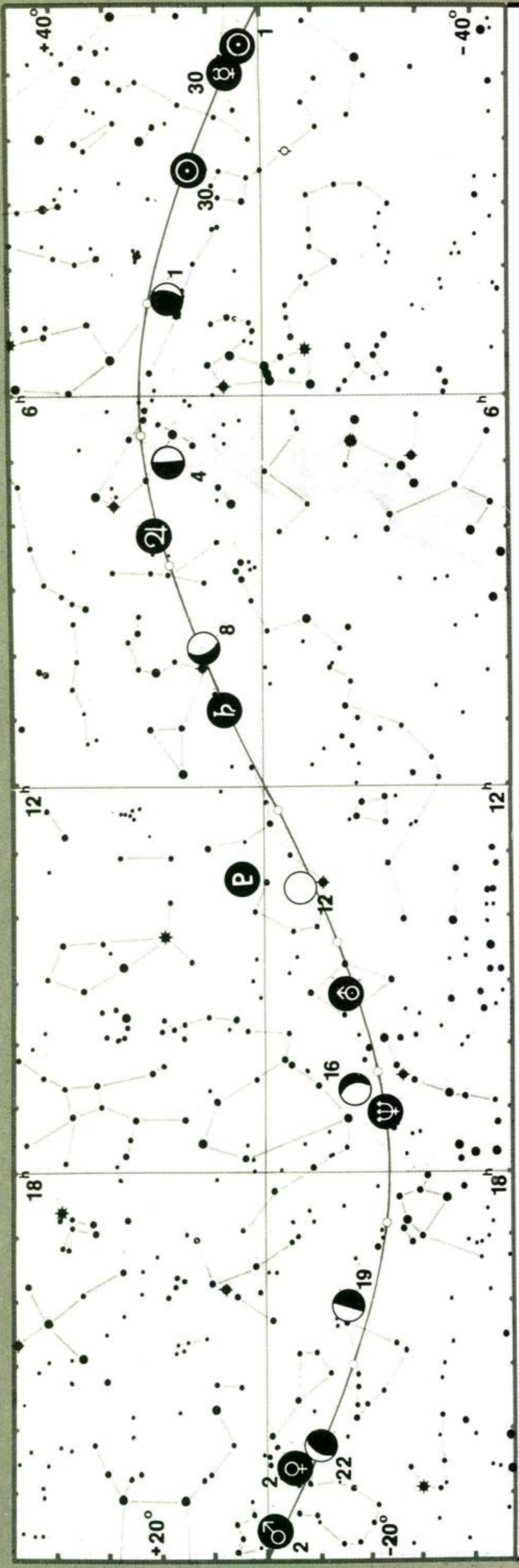
Pluto

Usually Pluto isn't worth mentioning, but since it reaches opposition on the 8th of April, it couldn't be totally neglected. It's at a distance of 29.3 A.U., and of magnitude 14. The only way you'll ever find it is to have a large scope and considerable patience. Aim your scope at the position given in Planet Finder, then map all the dimmest stars you see. Wait a few days and map again; comparing the two maps should reveal the elusive planet. (Hint: it's a *lot* easier to take some long-exposure, well-guided photos of the area.)

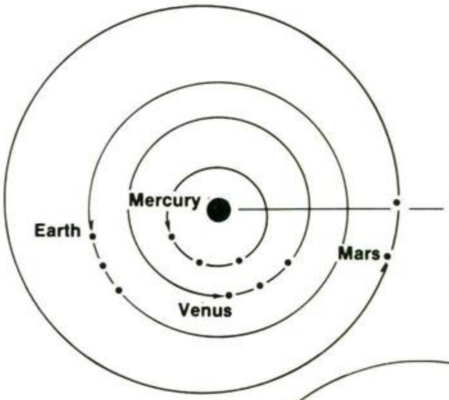
Meteors

April is the month for the Lyrids, a relatively minor shower of bright, medium-swift meteors coming from that part of the sky between Lyra and Hercules. The shower peaks fairly rapidly, being at quarter strength only two days on either side of the date of maximum.

The actual peak of the shower this year comes during daylight on the afternoon of the 22nd for North American watchers. Be out and looking for them when it gets dark that evening, but don't expect too many. The average hourly rate is around 15, and by the time the radiant point is well up in the sky (and you've moved onto the "leading" hemisphere of the planet), the Moon, just past last quarter, will be washing out the fainter shower members.

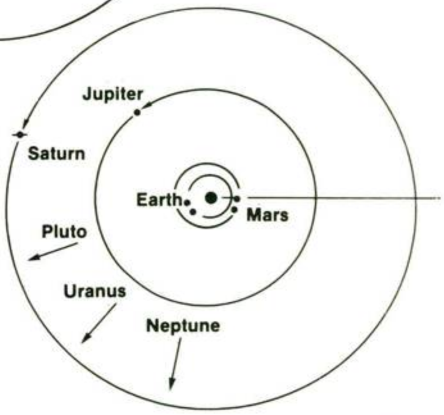

+40°
-40°
1
30
30
1
6h
6h
4
8
12h
12h
12
16
18h
18h
19
22
2
2
+20°
-20°

Planet Finder

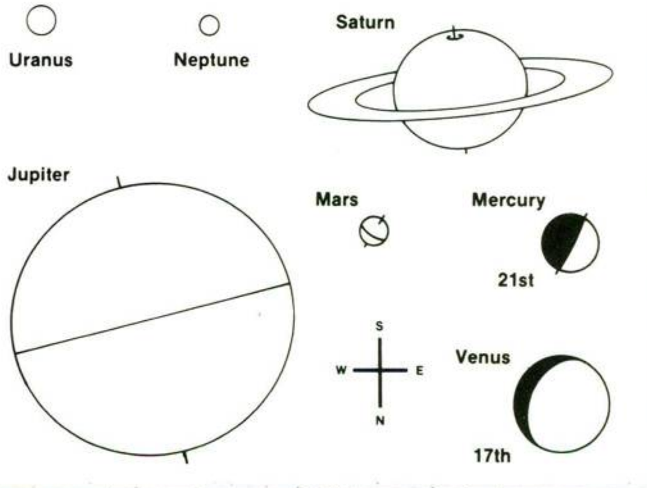

Mercury
Earth
Mars
Venus

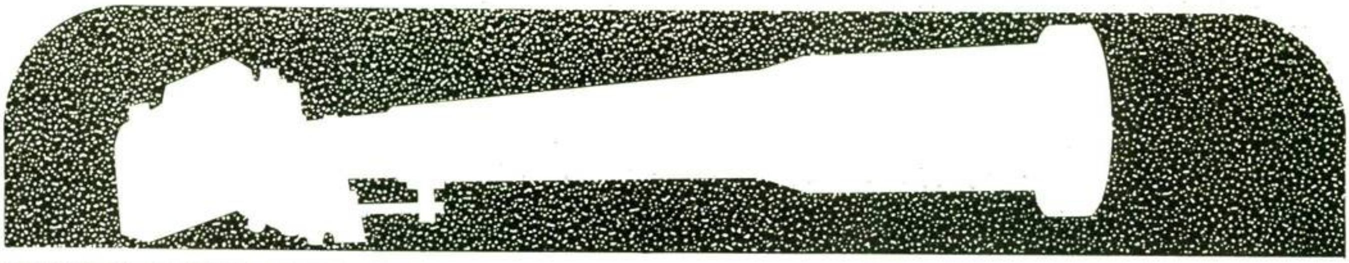
The positions of Mercury, Venus, Earth and Mars in their orbits are shown for the beginning, middle and end of the month. (Mars for the beginning and end only). The vernal equinox is the line at right.

The orbits of Earth, Mars, Jupiter and Saturn are shown at right. Earth and Mars' positions are for the first and last of the month; Jupiter and Saturn for mid-month. The outermost planets' directions are indicated.


Jupiter
Saturn
Earth
Mars
Pluto
Uranus
Neptune

Planet	Date	R.A. (1979.3)	Dec.	Mag.	Dist. (AU)
Mercury ☿	10	$23^h46.6^m$	-2°11.0′	+1.1	0.69
	21	$0^h14.9^m$	-1°01.6′	+0.6	0.84
	30	$0^h53.8^m$	2°38.7′	+0.3	0.98
Venus ♀	10	$23^h03.5^m$	-7°15.8′	-3.4	1.26
	30	$0^h32.8^m$	1°45.2′	-3.4	1.38
Mars ♂	15	$0^h24.1^m$	1°36.1′	+1.4	2.30
Jupiter ♃	15	$8^h07.8^m$	20°53.7′	-1.8	5.12
Saturn ♄	15	$10^h40.2^m$	10°35.6′	+0.7	8.63
Uranus ⛢	15	$15^h10.6^m$	-17°24.4′	5.7	17.77
Neptune ♆	15	$17^h18.5^m$	-21°39.3′	7.7	29.71
Pluto ♇	15	$13^h30.7^m$	9°35.3′	13.8	29.31


Uranus
Neptune
Saturn
Jupiter
Mars
Mercury
21st
S
W
E
N
Venus
17th



PHOTOGRAPHY IN ASTRONOMY

Piggybacking — Without a Drive

by
Richard Berry

Even if you don't have a telescope with a clock drive, you can take fine celestial time exposures. How? You can play the role of drive mechanism yourself as long as your telescope has some kind of slow motion controls. These controls may come with the telescope, or you may be able to adapt the simple design described here to your telescope. And before you say "I couldn't do that; it's sure to be too complicated," finish reading this article. You'll see that it isn't all that difficult, and the rewards (in terms of the photographs you'll be able to take) will repay your effort many times over.

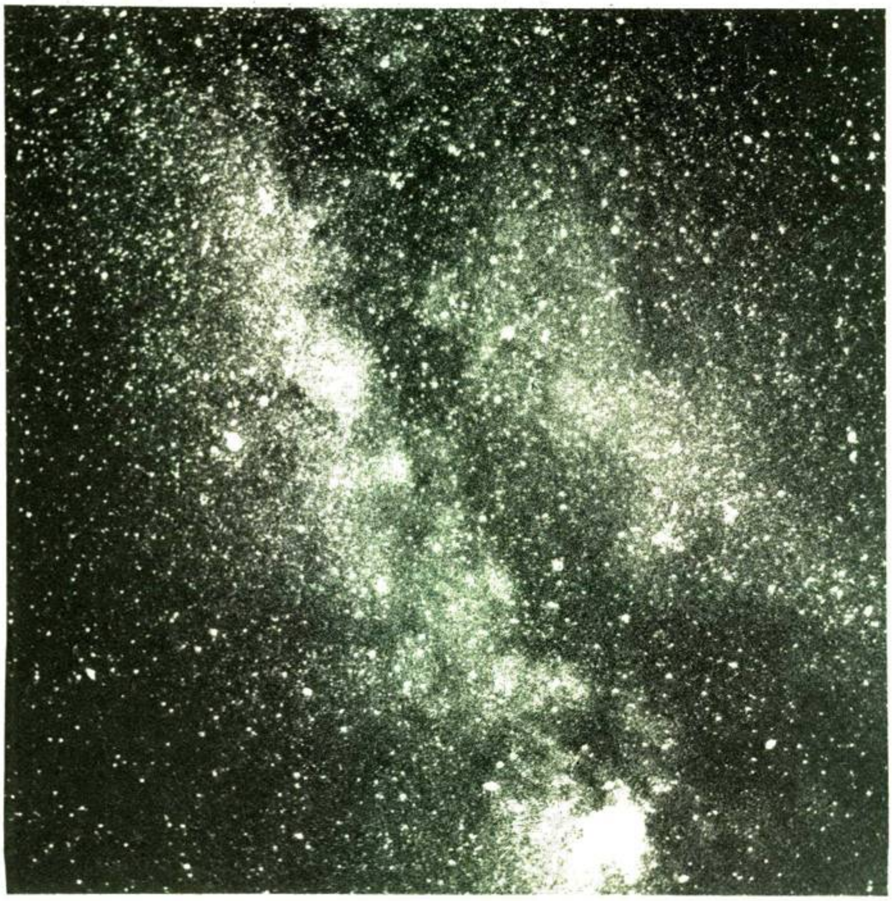
Let's assume that you have a 35 mm camera — they are common and most are very good. There are plenty of cameras that will work well: inexpensive SLRs, rangefinder cameras, even some of the more advanced 126 Instamatics.

The specifications on the lens are not too critical. If your camera's lens has a focal length somewhere between 40 and 55 mm, it's probably suitable for guided astrophotography. Even if you're dubious, it's far better to get out and try a few experiments than to worry about your camera's specifications.

If you simply put the camera on a tripod and point it at the night sky, the stars will trail into streaks within a few minutes. Star trails *are* worthy of experimentation in themselves (see "Astrophotography — With Camera Only!" June 1978), but let's assume that you can attach the camera to an equatorially mounted telescope. If you then center the telescope on a bright star and turn the slow motion controls to keep the star in the precise center of the field, you'd be taking a guided star photograph.

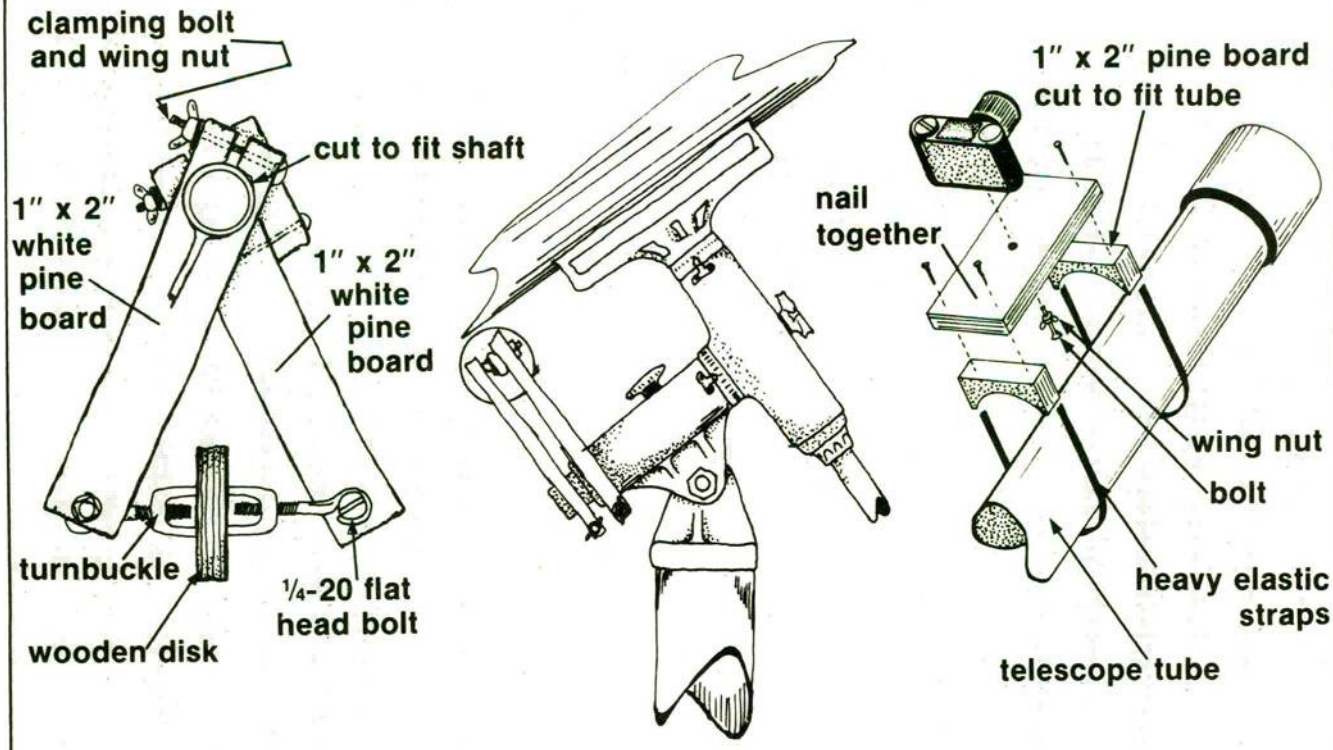
Now you probably already have several very pertinent questions. First, how do you keep the star image "perfectly centered"? Second, how should you set the camera's adjustments to photograph stars? And third, what sort of exposure should you use?

Let's discuss the notion of keeping the star "perfectly centered." Actually, that's overdoing it a bit: If you casually throw a few numbers around, you'll see that there's a substantial amount of leeway in tracking. With most 35 mm cameras, "perfect" star images are about one-thousandth of an inch across on the film. The camera lens has a focal length of 50 mm, or about two inches. With a little trigonometry, you'll find that the perfect star image works out to fill about 1/35th of a degree, or 1.4 minutes of arc. Regions of the sky near the celestial equator move through that angle in about seven seconds of time, and in the latitudes where most



Guiding by hand can get you started in deep sky astrophotography — even if your telescope isn't equipped with a clock drive. This 20-minute exposure of the Milky Way between Scutum and Cygnus shows the Great Rift, a dust cloud feature in our spiral arm. But beware — once you've taken one picture there'll be no stopping you!

HOMEMADE STAR TRACKERS



There are a couple of practical items to clear up before you begin astrophotography. One is attaching a camera to your telescope. The other is the matter of slow motion controls if your telescope doesn't have them now. Both can be solved with simple parts made from wood and ordinary kinds of hardware available everywhere. Because everybody's telescope is different, however, you'll have to figure out the best design for your particular 'scope.

A camera-holding platform can be made from two short bits of 1″ x 2″ white pine board cut to fit the telescope tube attached to a small square of plywood with a 1/4-inch hole drilled in the middle. The camera is held to the platform by a ¼-20 bolt and wing nut, and the platform is held to the telescope tube by big rubber bands, wide elastic strapping, rubber bungee cords, your Granddad's old suspenders — whatever is available to you. Place the camera and the platform close to the front of the telescope tube so that the tube doesn't block any part of the camera's view.

The homemade slow motion device works well with almost any kind of mounting — homemade or commercially made — that has a length of polar axis and its housing side-by-side. The principle of operation is simple: A wooden clamp grips the polar shaft and another clamp grips the housing. The ends of the shafts are joined by an ordinary hardware store turnbuckle, which, for ease of operation, has a wooden disk fitted tightly over it. Turning the turnbuckle makes it get shorter, thus forcing the wooden clamps to rotate and move the polar axis. Although such a device looks crude, it works very well. The details of the clamps are up to you, but nearly any telescope can be fitted with a pair.

ASTRONOMY readers live, the sky directly overhead moves that far in about ten seconds.

That means that *if you don't guide at all* for somewhere between seven and ten seconds, you'll still get nearly perfect star images. In fact, if you simply recentered the star every seven seconds, you'd be guiding as well as necessary.

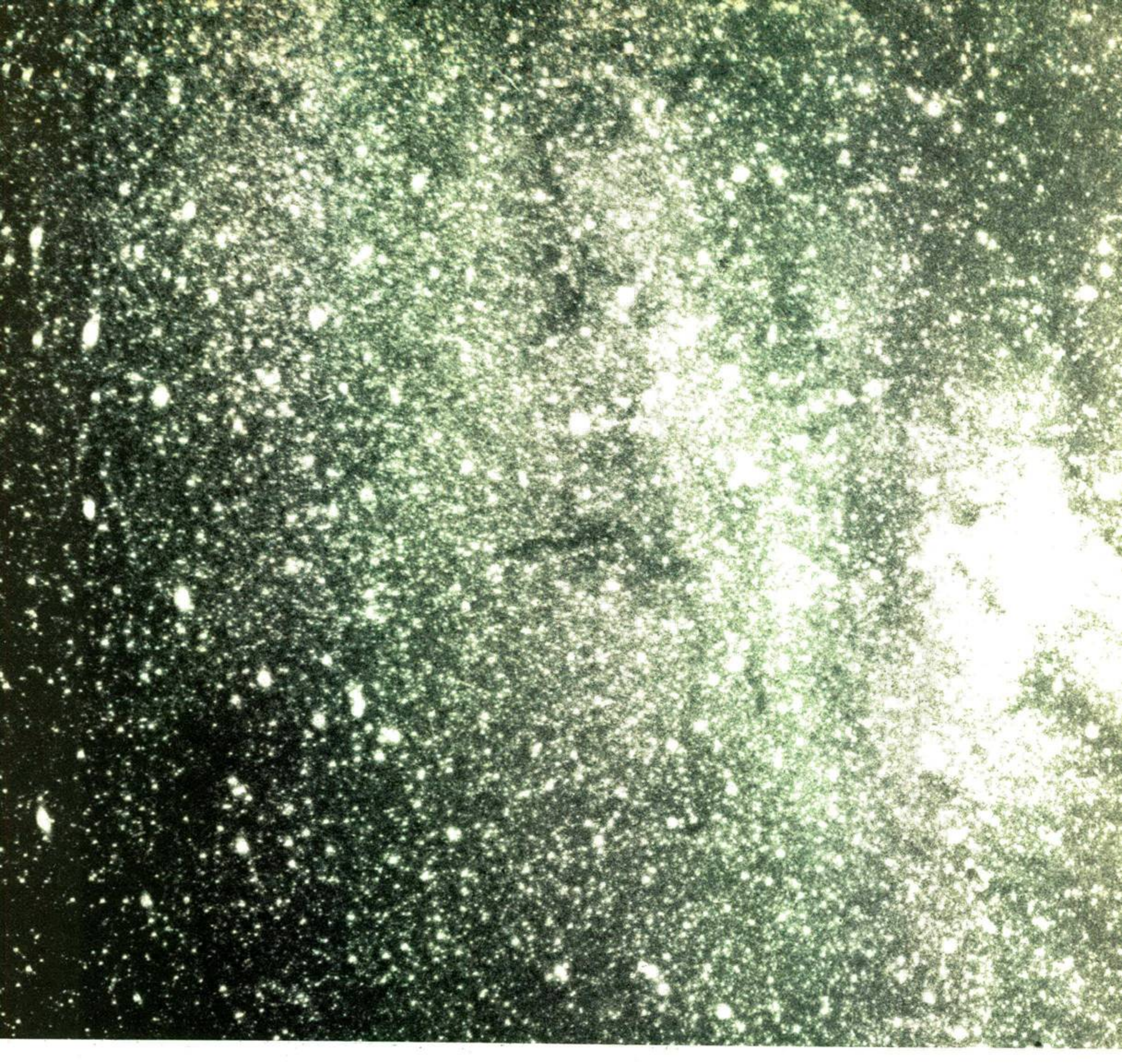
Now let's translate that into practical terms at the eyepiece of a telescope. You can try this yourself the next time you're out observing: Place a bright star — Spica is well placed now — in the center of the field, then count off seven seconds by the "one-lollipop, two-lollipop, three-lollipop" method. Notice how far the star drifts in the field during this time. You'll notice, though, that you'll have trouble telling where the center of the field is. Here's the trick: Take the eyepiece with crosshairs out of your finder and put it in the main telescope. Center the star again, then wait seven seconds to see how far it drifts.

Can you keep the star centered on the crosshairs by turning the slow motion controls? If you can keep it within the distance the star image drifts in seven seconds, you're tracking accurately enough to provide nearly perfect images. In practical everyday terms, you can do at least twice that badly before the tracking errors will show up.

Now you're ready to take a picture: How should you set the camera? There are three important settings: focus, aperture (or f/number), and speed (or exposure time). Because the stars are very distant, use the "infinity" focus setting. If your camera only shows "people, groups, and mountains" symbols, turn it to the "mountains" setting: This is equivalent to infinity.

Set the aperture to the smallest number on the dial. This may be 3.5, 2.8, 2.5, 2, 1.8 — whatever your camera has. Any of them will work with today's improved high speed films. The smaller the f/number, the bigger the lens opening, and the faster the camera will put enough exposure on the film.

Finally, there's exposure. The exposure time will probably run into several minutes — at least. You'll have



to find out by trial and error. You want to set the camera so that the shutter stays open for that entire time. Older cameras usually have a "B" and "T" setting on them: "B" means "bulb" and the shutter will stay open as long as you are pressing on the button. "T" means "time" and usually one push opens the shutter and the next push closes it. This is the ideal setting for time exposure astrophotography.

If your camera has "B" but not "T," the shutter will stay open only as long as you hold the shutter release. This could be inconvenient during a 30 minute exposure, so you can hold the shutter button down with rubber bands (if you're so inclined) or you can buy a *locking shutter-release cable* for a few dollars at a camera store. This gadget will let you gently open the shutter and then hold it open as long as you'd like.

If you own one of the fancy new electronically shuttered cameras, you'd best read its instruction manual carefully. The price of such electronic sophistication may be that the shutter consumes power (and drains the battery) as long as the shutter is open.

How long should you expose? It depends on how good your sky is and how sensitive (or "fast" in the photographic parlance) the film you're using is. Your best bet, no matter what kind of camera you're using, is one of the 400 ASA films: Ektachrome 400 for slides, Tri-X or Ilford's HP-5 for black and white, and Kodacolor 400 for color prints.

With any one of these films you should start with 1 to 5 minute exposures if you live in the city, 3 to 15 minute exposures if you live in the suburbs, and 10 to 40 minute exposures if you live under dark country skies. Any exposure — even the very shortest — of those mentioned will record plenty of stars. To capture the Milky Way or a faint comet, the longer exposures are more likely to be correct. In any case, your own experiments (be sure to keep records!) will tell you far more than any amount of advice given "long distance." The picture that looks best and shows what you want to show is best.

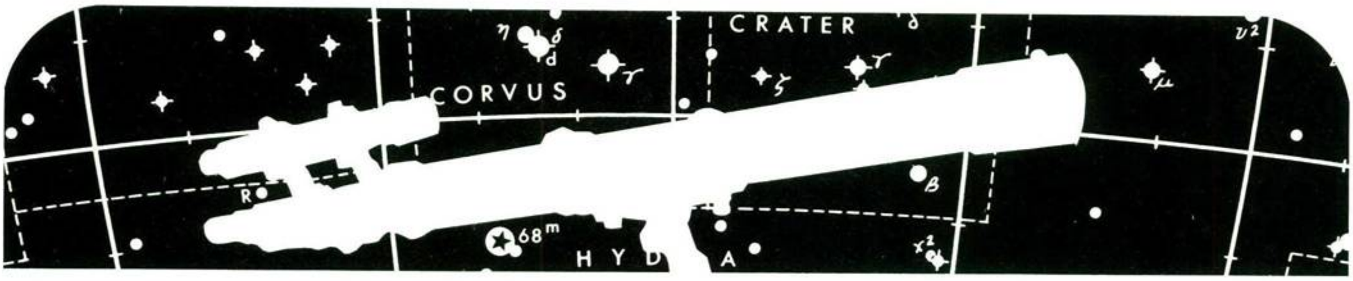
How do you actually go about using one of those devices for tracking (such

From the dark skies of northern Ontario, Canada, William Morrow exposed Tri-X film with his camera's 50 mm f/2 lens for six minutes to obtain this magnificent close-up on the North America Nebula, Deneb, and the rich starry Milky Way in Cygnus. He used a simple homemade mounting with a "observer powered" turnbuckle slow-motion device similar to the one described in this article.

as the one shown on page 33)? First, align the polar axis of the telescope mounting with the celestial pole as accurately as you normally do for visual observing. Point the telescope at a star near the celestial equator and near the meridian. Track it (without exposing any film) for a few minutes using just the right ascension slow-motion. If the star drifts very far either north or south of the cross hairs, try to align the polar axis more carefully, then track again. Within a few adjustments, even if you work almost randomly, you'll have an alignment accurate enough to give perfect images with a 35 mm camera.

Now, set up the camera, wind the turnbuckle all the way in (or out, depending on how yours works), aim at the stars you want to photograph, and settle yourself comfortably on a chair or stool arranged so that you can look into the eyepiece. If a guide star happens to be in the field of view, center it on the cross hairs. If one isn't, try to find one close by, center on it, and you're ready to go. Open the shutter of the camera, give a big sigh of ecstatic joy, and start "walking" your fingers slowly along the wooden disk (remember the old Yellow Pages commercials?). As your fingers walk along, the telescope will track the stars.

The longer the exposure goes, the more places you'll itch and the more powerful the need to stretch, yawn, sneeze, or sleep will become. You'll soon appreciate how long ten minutes really can be — but remember, you have seven seconds of grace to let the star drift while you get comfortable again. At the end of the exposure (ooops — did you forget to set your timer?) close the shutter, do a few minutes of vigorous calisthenics, then start the next exposure. And before you know it, you'll be hooked for life on astrophotography!



Celestial Software, Part 5:

How to Use a Star Atlas

by

Dewey Schwartzenburg

"Get your map right here, folks!" the hawker cries. "You can't tell the stars without a guide."

No, we're not tourists in Beverly Hills seeking the locations of the stars' homes. But as amateur astronomers seeking the locations of celestial objects, we are in as much need of a good guide as a lost Hollywood tourist.

Even those who know how to get to Procyon or the famed galaxy M-31 in Andromeda may well find themselves at a loss seeking out AR Aurigae and NGC-3521. A good star atlas will provide the answer — but *only* if you know how to read and use it properly. Reading and understanding maps is a mystery to many people, especially when it comes to using a map to find something in the real world. And star maps and atlases have their own peculiarities which have confused more than a few aspiring amateurs and led them down dark, weedy, dead-end roads in the sky.

Whatever star atlas you use, knowing a few simple facts and rules will enable you to avoid a great many mistakes and lost time. Then with a little practice in finding obscure binaries or galaxies or whatever, you'll soon find yourself an expert astronomical navigator.

The first rule to know (which applies to *many* endeavors, not only map-reading) is: "when all else fails, *follow directions*." The first thing you should do with any star atlas is thoroughly familiarize yourself with its system of rules, symbols, and conventions. Read its introduction very carefully, and take the time to examine the table of symbols until you have learned them perfectly. That way you won't make the mistake of confusing a galaxy with a globular or a binary with a variable.

Then look through the atlas slowly, examining each chart and noting how the different symbols appear when in place. Learn the format of the arrangement — star atlases (as opposed to whole-sky charts) begin with a north polar region, followed by one or more separate series of overlapping charts running around the entire sky and moving southward, with a final chart for the south polar region. Usually those atlases with only one series of charts between the north and south polar charts (such as **Norton's** and the **Edmund Mag 5**) will show the lines of right ascension and declination curved. Those which provide three or more separate series of charts, each running around the sky at a different declination (such as the **Skalnate Pleso Atlas Coeli** and the **SAO Star Atlas**), will have all the lines of right ascension straight, with only the lines of declination (other than the equator) curved.

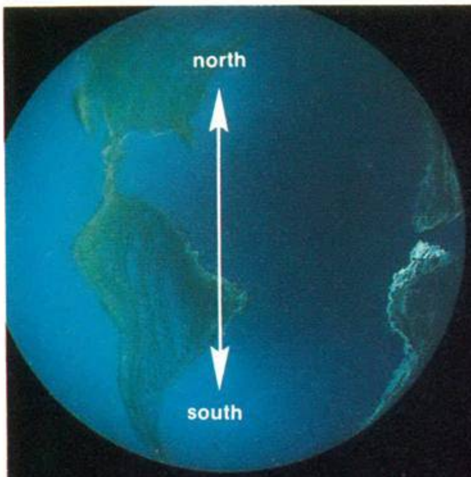
A particularly confusing aspect of star charts to many beginners is the fact that with north at the top, you'll find east to the *left* and west to the *right* — just the opposite of the way a land map appears. So if you're looking for an object said to be "east" of a particular star, and you move to the right of that star on your chart by terrestrial analogy, you'll quickly find yourself lost in a celestial quagmire.

The reason for this is that the sky is above us instead of below us like the Earth. Unlike the globe of our Earth, which we look down on from outside, we view the celestial sphere from the *inside*, which switches the directions of east and west. If, in looking down at the Earth, you orient yourself so that north is at the top, east will be to the right and west left. But in looking up and out at the globe of the sky, with the north celestial pole up, east and west will be reversed. If you hold a star chart up over your head with its top toward the north, east and west will come out correctly.

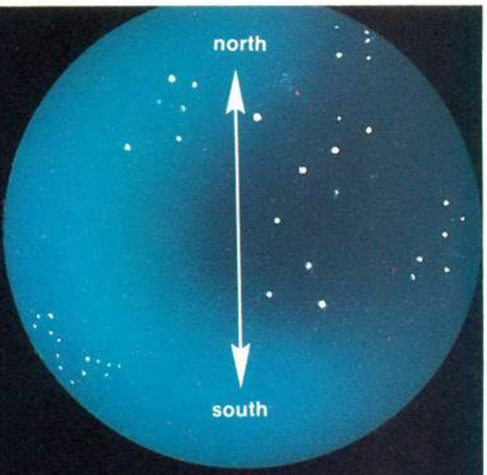
Often, in part to avoid this confusion (but usually only increasing it), one object will be said to be "following" or "preceding" another. This simply refers to the apparent rotation of the celestial sphere from east to west as Earth rotates. A *following object* is therefore one which lies to the east (left), and follows along *behind* its reference star as it moves across the sky, while a *preceding object* will be found *ahead* of the reference, to the west (right). One way to remember this is that we read from left to right — the same direction the stars will appear to move on a chart with north at the top.

In any case, be sure you know which

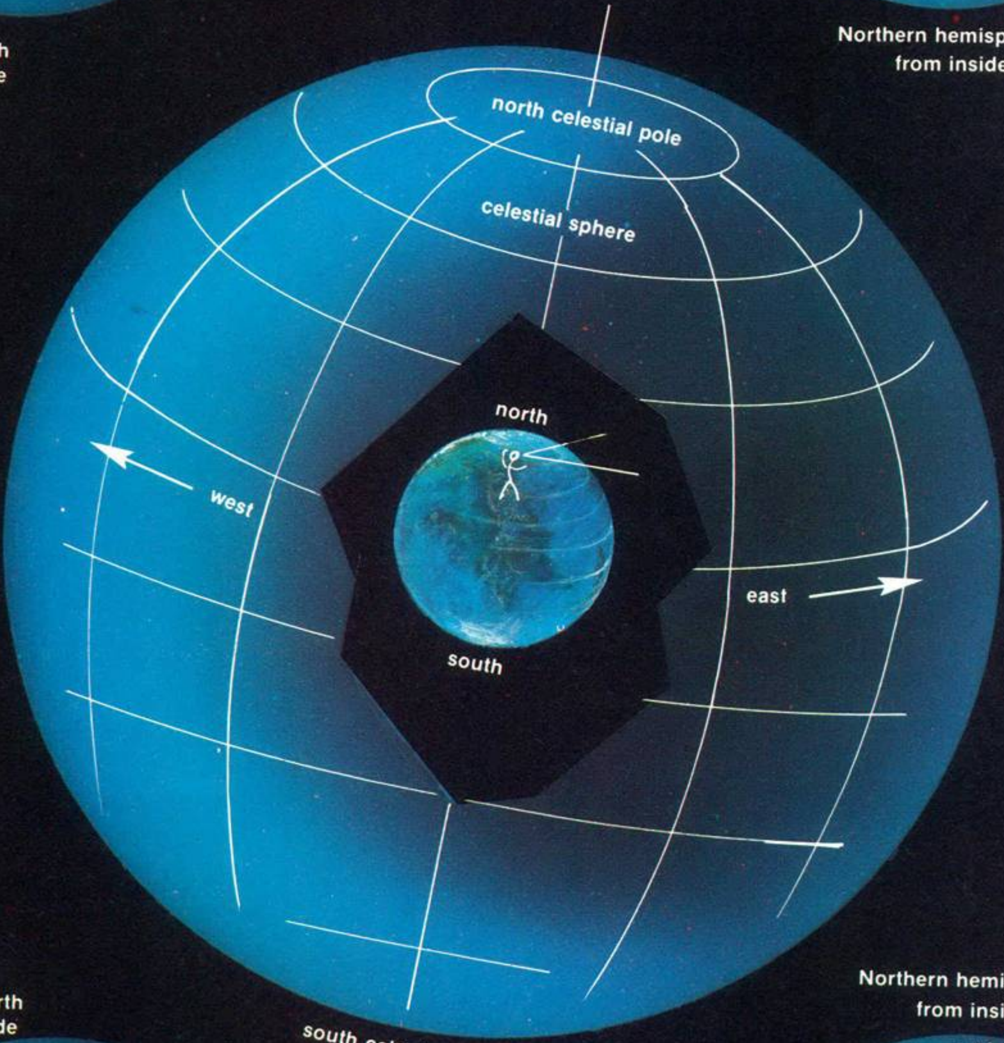
The celestial sphere is marked off in coordinates just like the Earth. Latitude on Earth corresponds to declination in the sky, and longitude on Earth becomes right ascension in the sky. However, because we observe the globe of the sky from the inside instead of looking down on it as we do with the globe of the Earth, east and west reverse their directions. North remains "up" for those in the northern hemisphere, while those south of the equator see the south celestial pole as "up" — so familiar constellations (such as Orion) appear upside down from the southern hemisphere. It is important to remember these differences in direction when using a star atlas.


north
south

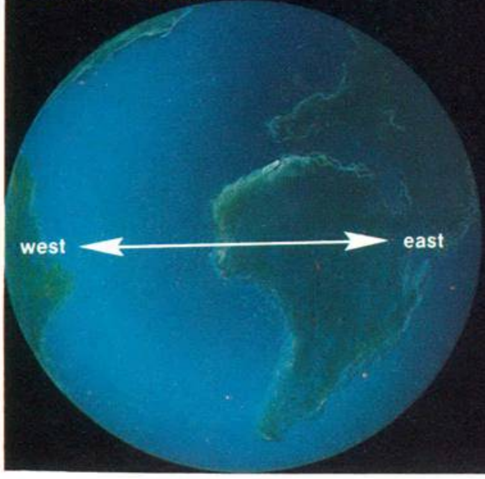
Globe of the Earth seen from outside


north
south

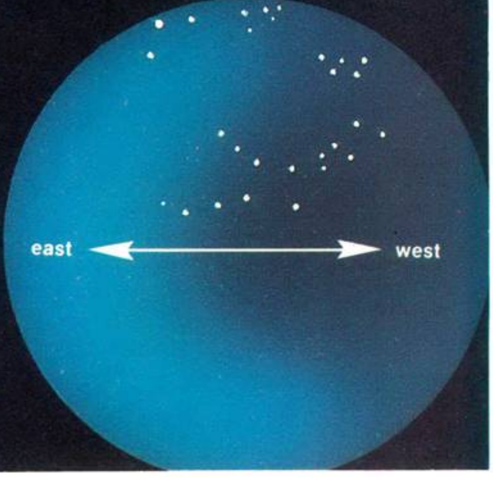
Northern hemisphere view of sky from inside celestial sphere

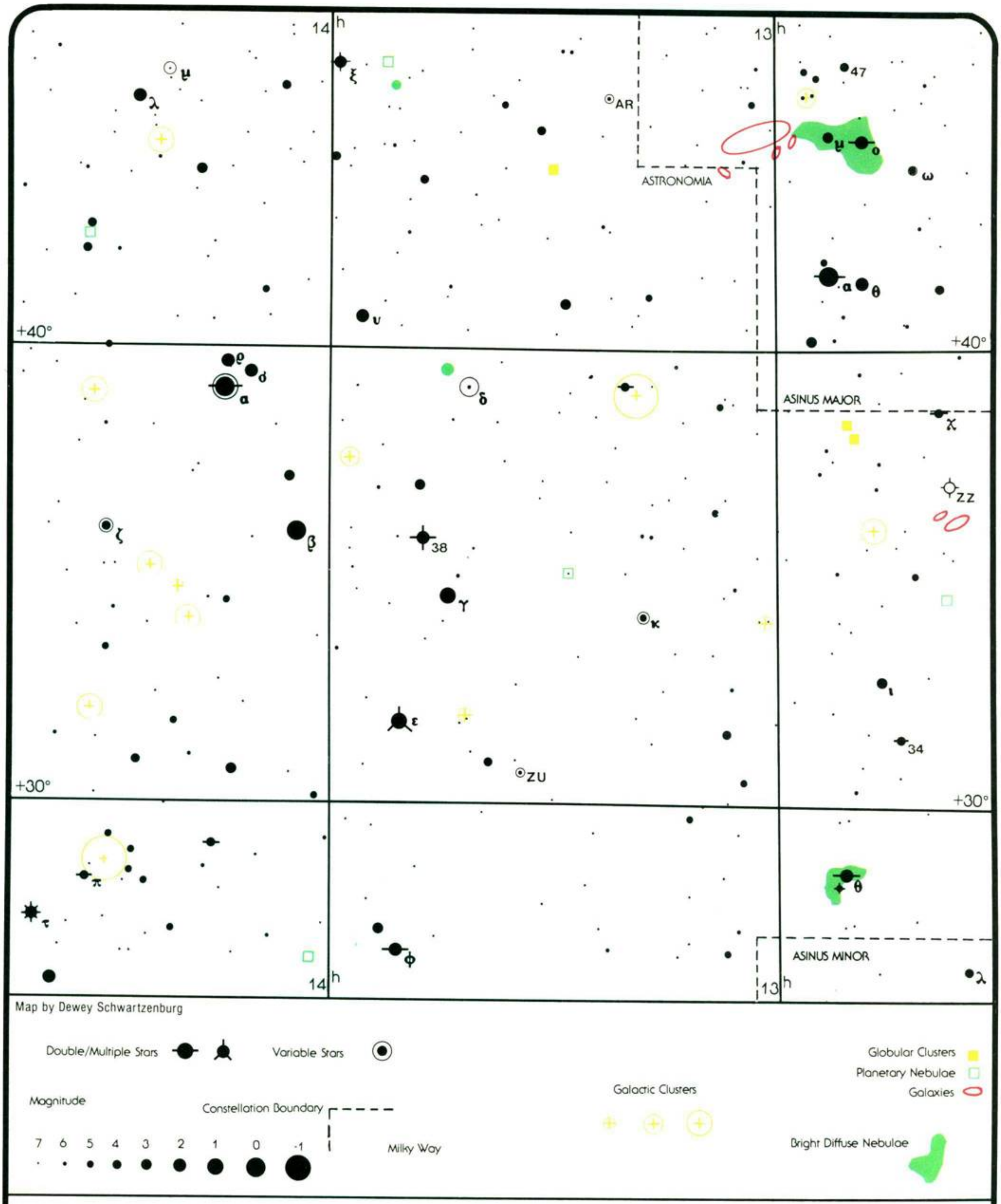

north celestial pole
celestial sphere
north
west
east
south
south celestial pole

Globe of the Earth seen from outside



Northern hemisphere view of sky from inside celestial sphere

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φ
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ASINUS MINOR
λ
Double/Multiple Stars
Variable Stars
Magnitude
7 6 5 4 3 2 1 0 -1
Constellation Boundary
Milky Way
Galactic Clusters
Globular Clusters
Planetary Nebulae
Galaxies
Bright Diffuse Nebulae

Map by Dewey Schwartzenburg

A star atlas can provide a great deal of information about celestial objects of interest to astronomers, but none have charts as inviting as the one shown above. An astronomer's dream, this region of the imaginary constellation Astronomia is amazingly rich. Double and multiple stars abound, along with a fascinating variety of asterisms and variables. Every catagory of sky objects is represented, including planetary and diffuse nebulae, galactic and globular clusters, and galaxies. Symbols for all these things are explained at the bottom of the chart. You may want to practice your chart-reading skills by planning an observing program for this fanciful region. What keys can you find to help you locate the various deep-sky objects? Be sure to remember to familiarize yourself with the symbols before attempting to read the chart. Would that all star charts were as rich and inviting as this one!

way is up. All star atlases are designed to be read with north at the top (except, of course, in the south polar region). But remember that in an inverting astronomical telescope, those star fields are going to be upside down from the way they're shown on the charts.

Getting all these directions straight — east and west, north and south, up and down — is not as difficult as it sounds, and once you have them programmed into your head they will work for all star atlases. But how do you then go about finding a particular object — say a variable star, or an open cluster — in your atlas? Hopefully you have its coordinates (right ascension and declination) there before you, or at least what constellation it's located in. How, then, do you find the right chart in the atlas?

Suppose first you have only the constellation. Unless you know the constellations and their arrangement awfully well, flipping through an atlas to find a particular one can be a frustrating activity. Instead, take a moment to check the atlas index, which will tell you in a second which chart your constellation is on.

If instead you have the right ascension and declination of your object (see "Right Ascension and Declination" in Equipment Atlas, ASTRONOMY, May 1978), your job is easier, provided you know the arrangement of the charts in your atlas. The declination will immediately tell you whether to look at one of the polar charts, or which of the middle series of charts will show your object. Then the right ascension is easy — the charts of virtually all atlases are arranged in order of increasing hour angle of right ascension, from 0^h to 24^h. Finding the right chart will be a snap.

The charts of most star atlases are marked off by lines of right ascension and declination, but generally these lines are at intervals of 10° for declination, and one hour (15° at the equator) for right ascension. For charts with a small scale, this won't be a problem. You can easily estimate the remaining coordinates and come close enough to readily locate your object. On more detailed charts, though, you may need to use a coordinate grid overlay. This is simply a transparent sheet marked by grid lines which can be placed on any part of any chart for a more accurate reading of position. If your atlas has such an overlay, use it. It will save a lot of time in the long run over the "hunt and search" method of scanning the area: "I *know* it's right around here somewhere!"

Actually it may not be there at all, if you've forgotten a very important fact. On star charts, right ascension increases from *right* to *left* — so as you look across the chart in normal reading fashion (from left to right), the hour angles will go 18, 17, 16, 15, etc. If you forget this, and you're searching for something at, say, 17^h20^m, you'll find the vertical line for 17^h and look about one-third of the way to the next line — that is, you'll be searching the area of 16^h40^m instead of 17^h20^m. So remember to look at the border legend of the chart and read right ascension as increasing from *right* to *left*.

Again, though, once you have this programmed into your brain, you'll never have a problem with any star chart.

So now you've found that obscure binary or faint galaxy or whatever in your atlas. How do you go about using your star chart to find it in the sky? First, take your atlas or chart with you to your telescope. Unless you have a photographic memory, it simply won't work to dash out and start searching the sky. "But," you protest, "I can't see the chart out there in the dark!" Of course you can. But not with a bright light — *always* use a dim red flashlight so that the dark adaptation of your eyes isn't lost. You'll need such a light anyway, to find the right eyepieces, read your setting circles, and lots of other jobs out there in the dark.

And unless you are very familiar with the constellations, you'll find a *planisphere* helpful in addition to your more detailed star atlas. (A planisphere is a chart of the whole sky visible from a particular latitude with a rotatable covering horizon-mask to show what can be seen and where it will be at any hour of any day.) The planisphere will tell you in what general direction to point your telescope, and then the star chart will enable you to locate the precise point within that area.

One of the best tricks to use in locating an object for those with equatorial mounts is to find a nearby, relatively bright star at about the same declination. Then, once you have the star in your field of view, moving the telescope around its right ascension axis the right amount should bring the object into sight. Be sure you're aligned correctly onto the north celestial pole if you use this method, though. If the object is following (see above), you can simply shut off the drive and wait for the apparent turning of the celestial sphere to bring your goal into view.

Star-hopping is another way to locate a dim object. Map out a route for yourself on your star chart, moving from brighter to dimmer stars as you approach your object, making the final jump from a star close to it. (This method is often used to find the Great Galaxy in Andromeda [M-31] visually, by star-hopping from the Great Square of Pegasus.) Make sure your route is clear and easy to follow, though, or you may make a left turn at the wrong star.

Star Atlases

Below is a list of star atlases in common use today. They are arranged roughly in order of increasing detail and limiting magnitude.

Edmund Mag 5 Star Atlas, Sam Brown (1975). 6 charts, no south polar chart. Mag. limit 5.

Constellations: A Concise Guide in Colour, Josef Klepesta and Antonin Rukl (1969). 87 charts, plus 4 seasonal and 2 polar charts. Mag. limit 5.

Seasonal Star Charts, James S. Sweeney, Jr. (1972). 8 charts plus planisphere. Mag. limit 5.75.

Norton's Star Atlas and Reference Handbook, Arthur P. Norton (16th edition, 1973). 8 charts plus two galactic charts. Mag. limit 6.3.

Color Star Atlas, Patrick Moore (1973). 8 charts plus seasonal maps. Mag. limit 6.5.

The Telescope Handbook and Star Atlas, Neale E. Howard (updated edition, 1975). 14 charts. Mag. limit 6.5.

Handbook of the Constellations, Hans Vehrenberg and Dieter Blank (1973). 57 constellation charts plus 3 whole-sky charts. Mag. limit 6.25.

A Field Guide to the Stars and Planets, Donald H. Menzel (1975). 54 photographic charts, each twice (with and without labeling). Mag. limit about 8-10.

Atlas of the Heavens, Antonin Becvar (1962, field edition 1969, desk edition 1976). 16 charts. Mag. limit 7.75.

Atlas Borealis, Atlas Eclipticalis, Atlas Australis; Antonin Becvar (3 volumes, 1962, 1964). 80 charts, stars only. Mag. limit 10.0 for binaries and variables; others fainter.

Star Atlas of Reference Stars and Nonstellar Objects, Smithsonian Astrophysical Observatory (1969). 152 charts. Mag. limit 9.0.

Lick Sky Atlas, Lick Observatory. 160 photographic charts to declination -37°. Mag. limit varies: very faint.

Finally, if you're willing to take the trouble to make the adjustments, you can directly use the setting circles on your telescope to zero in on your object.

A star atlas is an essential aid to astronomical observations. With a little practice and experience in use, you'll quickly find that you don't have to stick to the main, "easy" objects — you can travel anywhere you want in the sky to see the local sights.

Meade precision 6" and 8" reflecting telescope systems give you full photo-visual capabilities.

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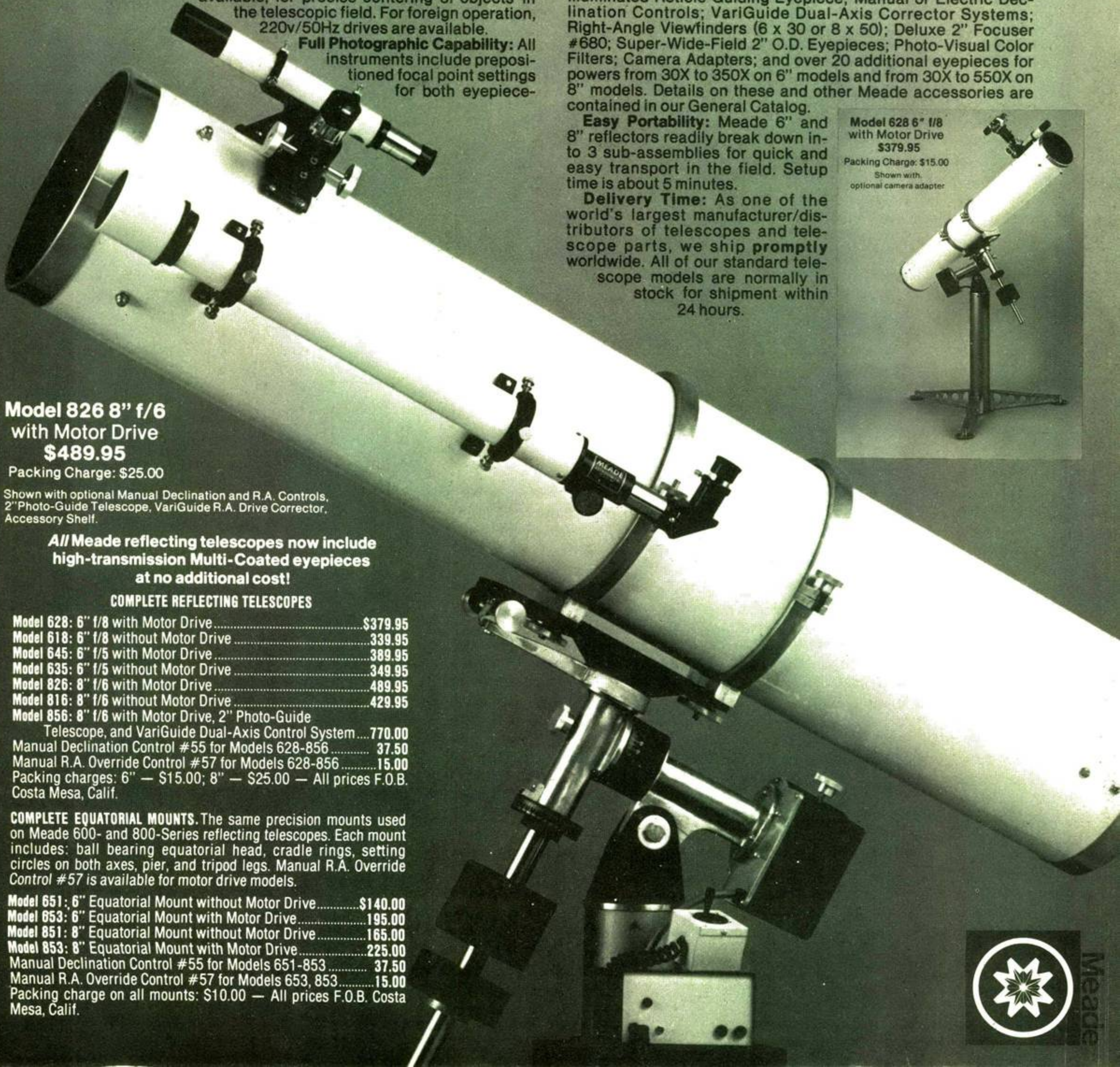

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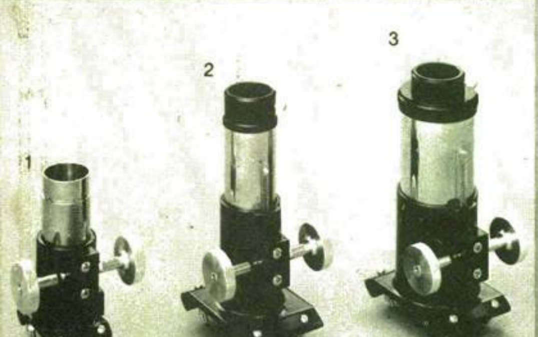

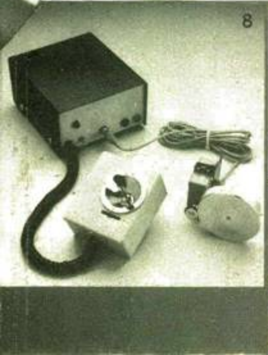

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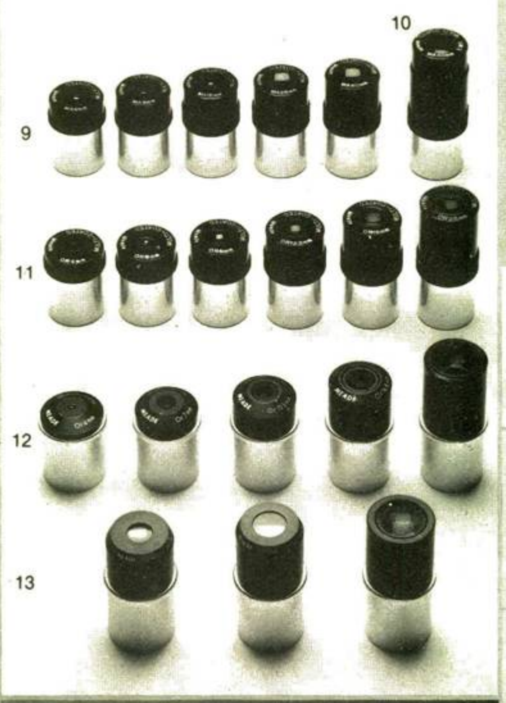

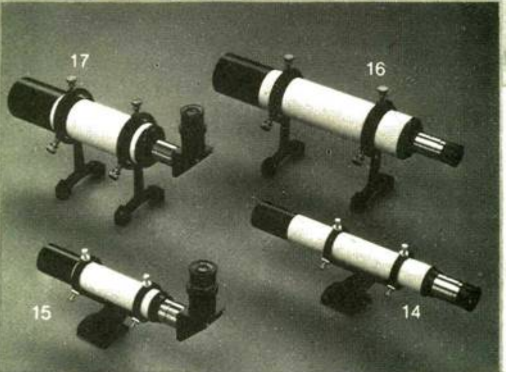

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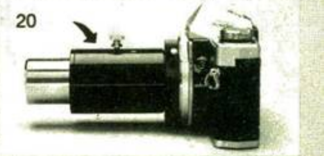

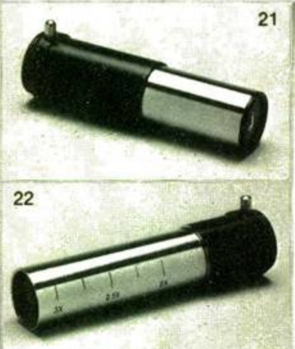

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GAZER'S GAZETTE

Halos, Rings, and Arcs in the Sky

by

James Mallmann

Have you ever wondered if there's something new for you to see in the sky? If you've been observing for any time at all, you might not think so, but don't be too hasty. How familiar are you with unusual patterns of light and color in the sky? How well do you understand the many effects you get when light from the Sun (or Moon) interacts with water drops or ice crystals in our atmosphere? Not much, you say? Well, here's a chance for you to do some daytime observing of unusual celestial objects.

These effects are visible without aid, any place in the world, during any time of the year, and most people have never seen them because they aren't aware of their existence. (This probably happens because you never notice the familiar around you.) Here we'll show you a few of the more noticeable atmospheric optical effects and what causes them, while mentioning a few of the uncommon ones.

Rainbows

Now who hasn't seen a rainbow? And just what, you may ask, is new about one? Well, they aren't new, but maybe there's more to them than you think.

To start with, the rainbow you see in the sky is only part of a full circle. When you next see one, turn your back to the Sun and draw an imaginary line from it straight through your eye; this line will pass through the center of the rainbow's circle. Now if you look at the apparent center of the circle (or what amounts to the same thing, the shadow of your head on the ground) and measure the angular separation between your shadow and the edge of the rainbow, you'll find in every case an angle of 42°. Because of this, you can only see a rainbow when the elevation of the Sun above the horizon is less than 42°. If the Sun were higher, the entire rainbow circle would be lost against the ground. This also means that the biggest and most complete rainbows occur when the Sun's on the horizon. (The next time you're out in the yard with a hose, put it on fine spray and stand, aiming it away from you, with your back to the Sun. You'll make a little rainbow, a miniature version of the big thing.)

When rays of light from the Sun enter a spherical drop of water, they reflect internally and leave the drop in directions that are close to the reverse of their incoming directions. This is why a rainbow always appears on the side of the sky away from the Sun.

As the light enters and leaves the raindrops, it's refracted as well, just like in a prism, separating the white light into its constituent colors. Red light is refracted less than violet light, and so tinges the outer edges of the bow red. The inner edges become violet, with the other spectral colors arrayed in between.

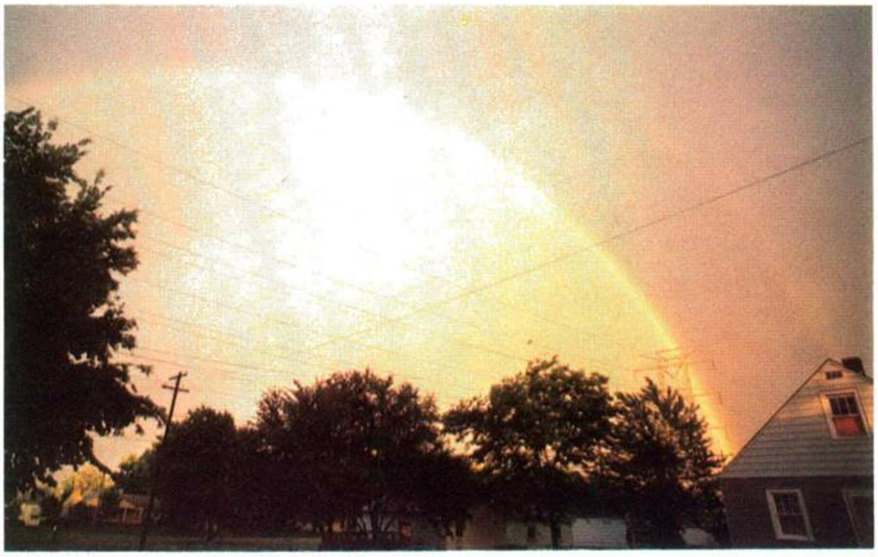
Not all light rays leaving the raindrops add to the brightness of the bow, and these rays generate a feature most often missed by the casual observer. The sky inside the rainbow is brighter than that outside. Take a look at photograph 1, where you can see the effect clearly.

That same photo also shows a faint secondary rainbow outside the primary one. The secondary bow happens when rays of light experience two internal reflections before leaving. In every case, it's fainter than the primary bow, and the color-order is reversed: red on the inside, violet to the outside. The primary and secondary bows are always separated by 8°. Diagram A shows the light-ray paths creating the primary and secondary rainbows.

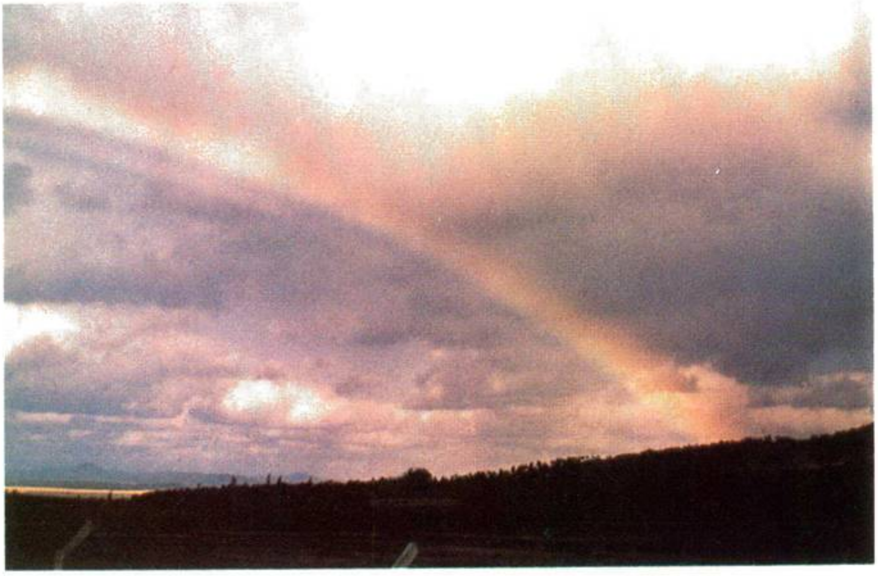
These features of rainbows all come about through reflection and refraction, but some patterns of light can appear which are due to a process called *interference*. The colors you see in a soap bubble or in an oil slick on pavement or water are examples of interference phenomena. What's happening is that light waves are reflected back on themselves just out-of-step, causing some colors to cancel out. Sometimes when a rainbow appears, you may see faint additional arcs, usually pink and green, inside the primary bow beyond the violet region. They are called supernumerary arcs, and photo 2 shows an example of one.

Ice Crystal Phenomena

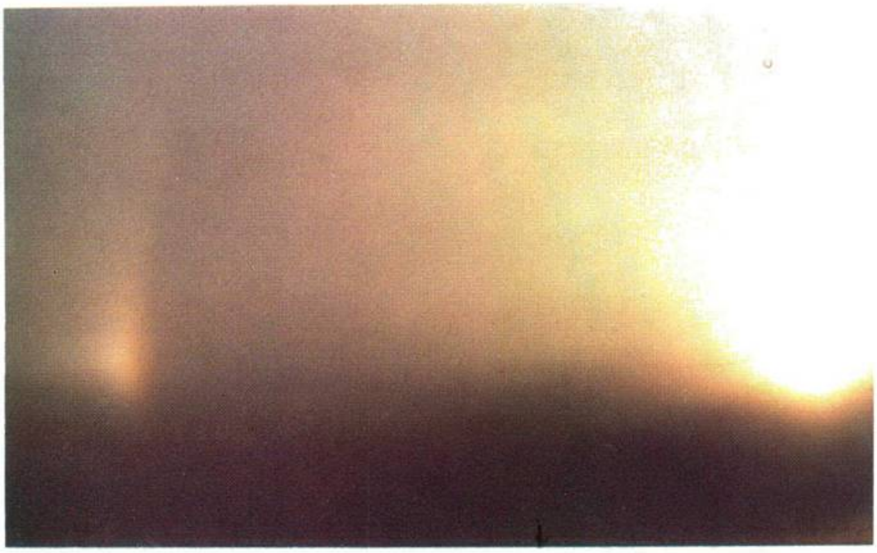
Falling raindrops are spherical, and all possible orientations of spherical drops are equal, so when light rays

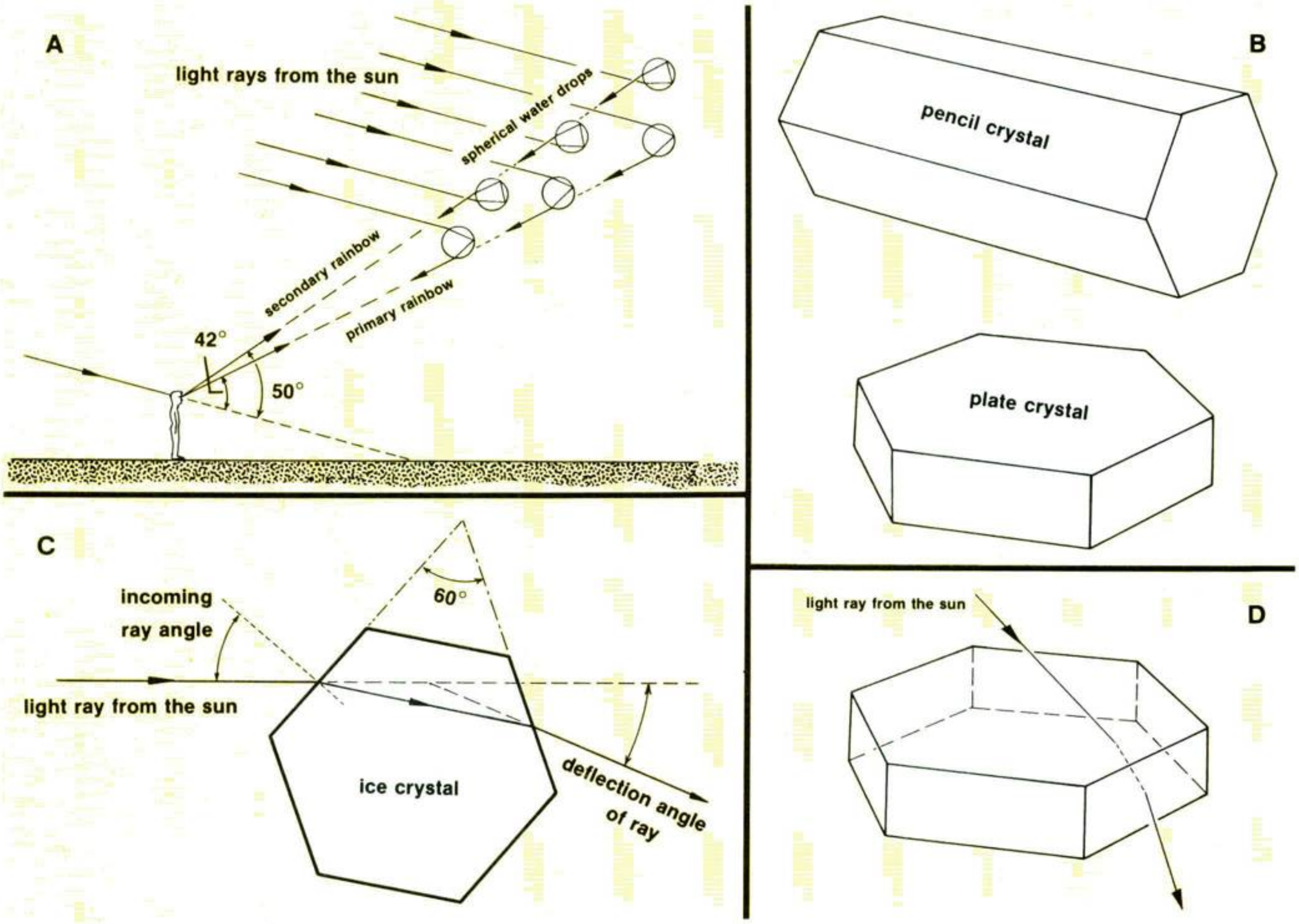


Photograph 1 (above) shows primary and secondary rainbows glowing after a summer thunderstorm. Notice the contrast in sky brightness inside and outside the primary rainbow. (Unless otherwise noted, all illustrations are by the author.)



Above: photograph 2 shows supernumerary arcs inside a primary rainbow. The supernumerary arcs (on the inside) are brightest near the top of the rainbow, while the rainbow itself is brightest near the ground. Photo by Earl Sager. Photograph 3 (below) is of a sun dog to the left of the Sun, taken one April afternoon.





In diagram A, you see schematically how light from the Sun is reflected and refracted into a rainbow. Diagram B shows the commonest types of ice crystals: at top is the pencil variety; at bottom, the plate type. Diagram C indicates how rays of sunlight are bent by the crystal as they pass through it. The deflections caused by passage through the top and side are illustrated in diagram D.

pass through raindrops, the circular patterns of rainbows are the result. It's not nearly as simple with the hexagonal ice crystals usually present in the atmosphere throughout the year. Diagram B shows two forms of such crystals. The upper one, called a *pencil crystal*, and the lower, called a *plate crystal*, look like long and short segments of common wooden pencils. Because these crystals aren't round like raindrops, they can assume different orientations to the light rays, giving rise to a great assortment of light patterns in the sky.

In calm air, the relatively large plate crystals tend to fall with their large faces horizontal, fluttering like a leaf or small bit of paper. Sunlight passing through conglomerations of them creates one of the most frequently seen optical effects — *sun dogs*. Sometimes called mock suns or parhelia, sun dogs are concentrations of light at the same altitude above the horizon as the Sun, and to the left and right of it.

A ray of light that ends up in a sun dog passes through alternate vertical side faces of a plate crystal. (Diagram C shows the path taken.) You might expect air motions to rotate these plates around, naturally changing the angle at which the incoming ray meets the face of the crystal. But due to the physical and optical properties of the crystals, for a rather wide range of incoming angles (anywhere between 31°and 52°), the outgoing rays all stay within a degree or so of 22°. Because the crystals with differing orientations still send light out in approximately the same direction, light tends to "collect" near the 22° angle. Sun dogs are spots of collected light 22° to the right and left of the Sun.

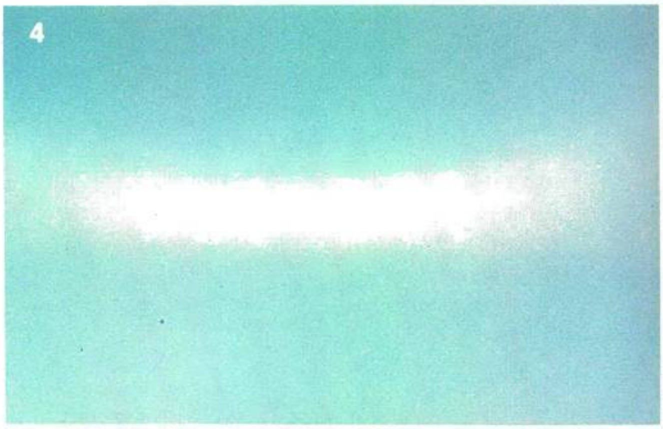
Red light being bent by the crystals less than violet, the red edges of the sun dog are the inner ones. Photograph 3 shows a typical sun dog to the left of the Sun. In this case, the vertical elongation of the sun dog means the ice crystals are not all aligned exactly horizontally, ranging here up to about 15° out of level with the horizon.

You won't ever confuse sun dogs with rainbows if you stop and think for a minute. Sun dogs are on the same side of the sky as the Sun, while rainbows lie opposite it. In addition, the colors are reversely arranged — sun dogs have red inner edges while those of rainbows are blue.

When there are very small crystals in the atmosphere, they may lie at any orientation. Such randomly oriented crystals cause a circle of light around the Sun called the *22° halo* (see photo 8). They also happen rather commonly around the Moon. The explanation for both is the same as that for sun dogs, except that the crystals are aligned in no particular order. If you want, you can think of the 22° halo as a circular sun dog.

Sun dogs and the 22° halo come from light rays passing through crystal faces that make an angle of 60° with each other. Light rays also pass through pairs of crystal faces that make an angle of 90° with one another. One 90° refraction effect, relatively rare, is a circle around the Sun with an angular separation of 46° — which is called, of course, the *46° halo*. Like the one at 22°, this halo comes from crystals in totally random orientations.

When the plate crystals have their large faces horizontal, light rays entering the top face and exiting through a side face, as shown in diagram D, produce a particularly bright and colorful display called the *circumzenithal arc*. Photograph 4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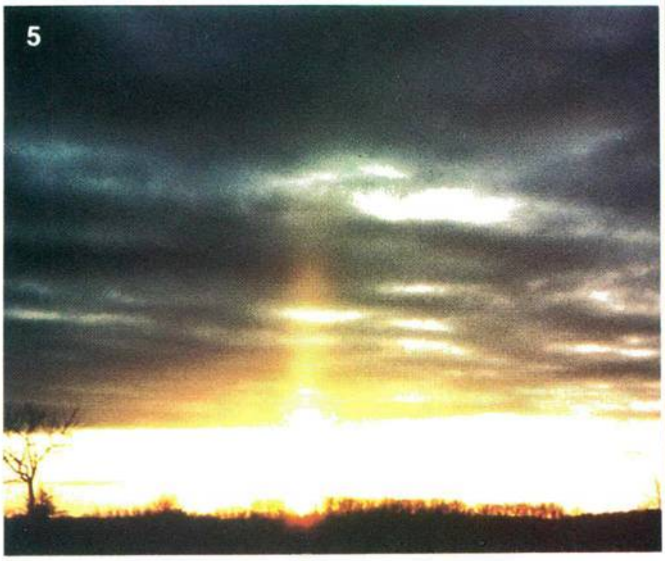
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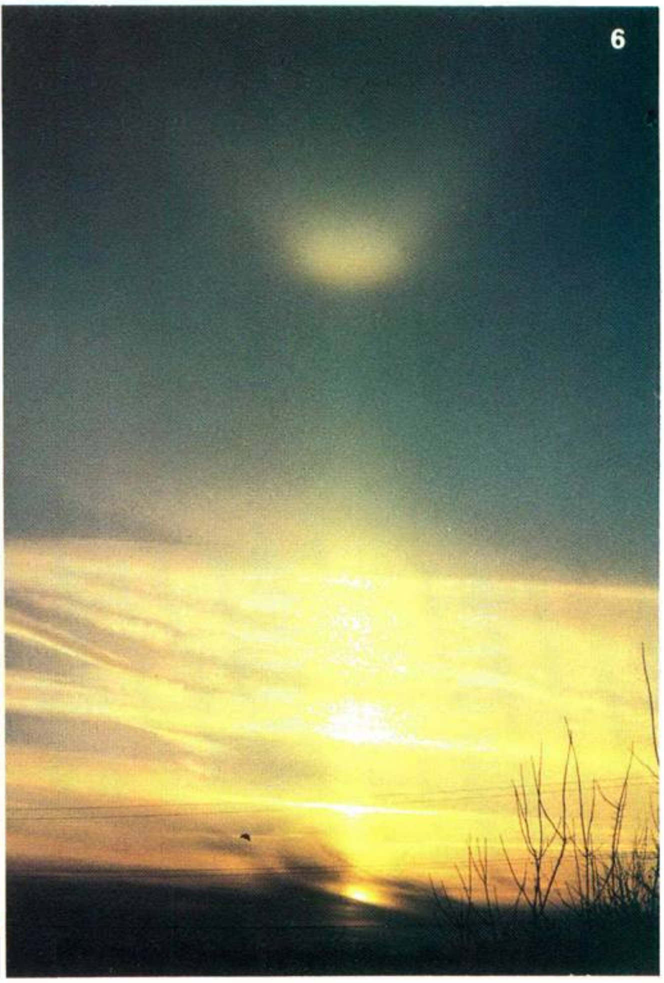
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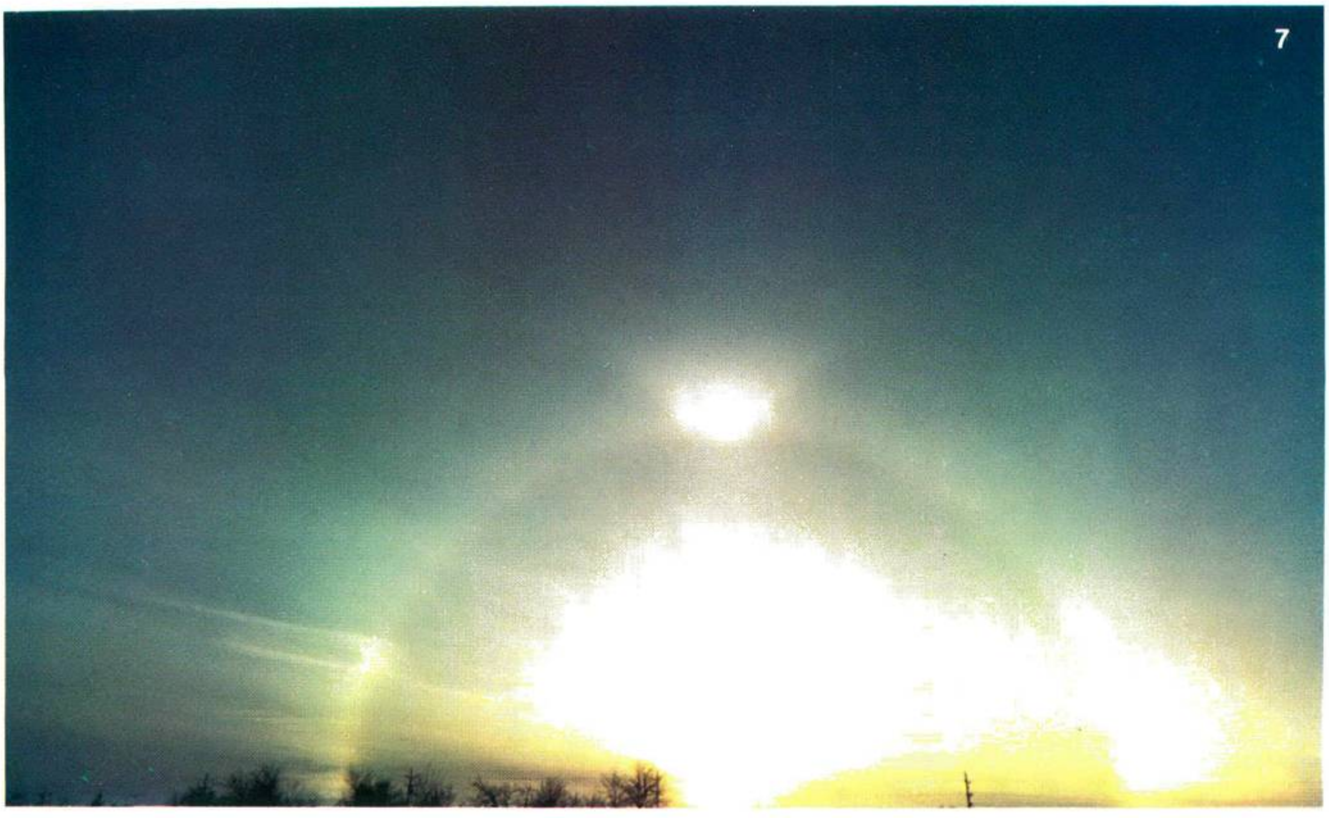
Photograph 4 (at top) is of a circumzenithal arc and was shot at the same time as photograph 3. Both the arc and the sun dog were caused by horizontal plate crystals. Photo 5 is of a sun pillar above the setting Sun. Photo by Robert G. Greenler.

Photograph 6: this sun pillar with an upper tangential arc happened on a February afternoon at sunset. Below: photograph 7 shows a complex display with the 22° halo, sun dogs, a sun pillar, and the upper tangential arc — all at once!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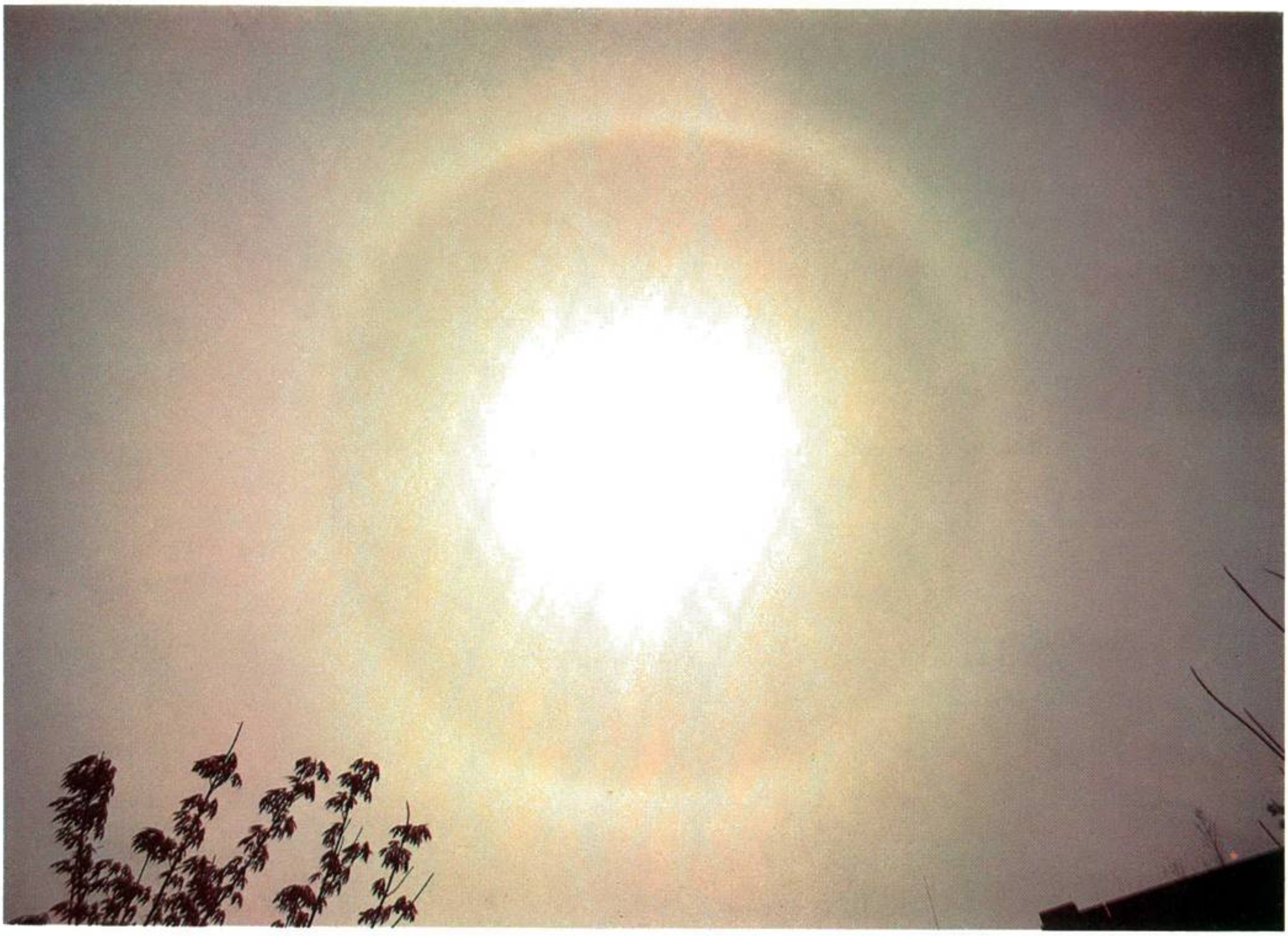

Photograph 8 shows a common 22° halo around the Sun. This shot was made in July, but these halos can be seen throughout the year, often around the Moon as well.

shows an example. As you'd expect from the name, this arc is circular with its center at the zenith (the point on the sky directly overhead). The angular distance of the circumzenithal arc from the Sun can vary from 46° to 57°, depending on the altitude of the Sun. Take a look overhead for this arc when you can see sun dogs, for both effects come about from horizontal plate crystals and may happen simultaneously.

The simplest interaction of sunlight rays with ice crystals occurs when the light reflects off the outer surface of the crystals. Sometimes, if the Sun is near the horizon, you'll see light reflecting off the top and bottom faces of approximately horizontal plate crystals, producing a vertical column of light directly above the Sun. This is called a *sun pillar*. They can also happen under the same atmospheric conditions at night, when the pillars form over artificial lights. Photograph 5 shows what a sun pillar looks like.

Sun pillars can also occur when light reflects off the long side faces of pencil crystals. One such pillar can be seen in photograph 6, but there's something else in that photo besides. That v-shaped splash of light above the pillar is an *upper tangential arc*. If the 22° halo were visible, this arc would be tangent to it. The upper tangential arc appears when light rays pass through alternate side faces of the same collection of pencil crystals that created the sun pillar, and were then refracted.

Sometimes clouds of different crystal types will lie between your eye and the Sun, which makes for even more complex displays. The display in photograph 7, for example, includes sun dogs, the 22° halo, a sun pillar, and the upper tangential arc. The 46° halo and the circumzenithal arc, both of which lay outside the camera's field of view, were also part of the display.

Doesn't it seem strange that rainbows are so well-known to everyone, but only relatively few people are aware of the variety of patterns caused by ice crystals? This, by the way, has been really only an introduction; other effects include the circumscribed halo, the circumhorizontal arc, the parhelic circle, Parry arcs, the arcs of Lowitz, anthelic arcs, and more.

Although sky effects are caused mostly by ice crystals, they can occur throughout the year since the upper extent of the atmosphere is always bitterly cold. (One day during the summer of 1977, I saw a halo when the air temperature at ground level was 99° Fahrenheit.) However, they happen more often during the spring months. So if you remember to look at the sky each day for the next few weeks, you're almost certain to see at least a few sun dogs or a 22° halo, and if you keep at it regularly, you may also glimpse phenomena happening only occasionally during a lifetime.

Want to Know More?

About the only readily available book on this subject (and a whole lot of other related ones) is **The Nature of Light & Colour in the Open Air** by M. Minnaert (Dover Publications, 180 Varick St., New York, NY 10014). The author explains, in simple terms, a great many simple and unusual atmospheric optical effects. Your public library may have a copy, and some bookstores carry it.

James Mallmann is Professor of physics at Milwaukee School of Engineering. He has been working on a project for the last 10 years to greatly increase our understanding of how ice crystals give rise to color effects in the atmosphere.

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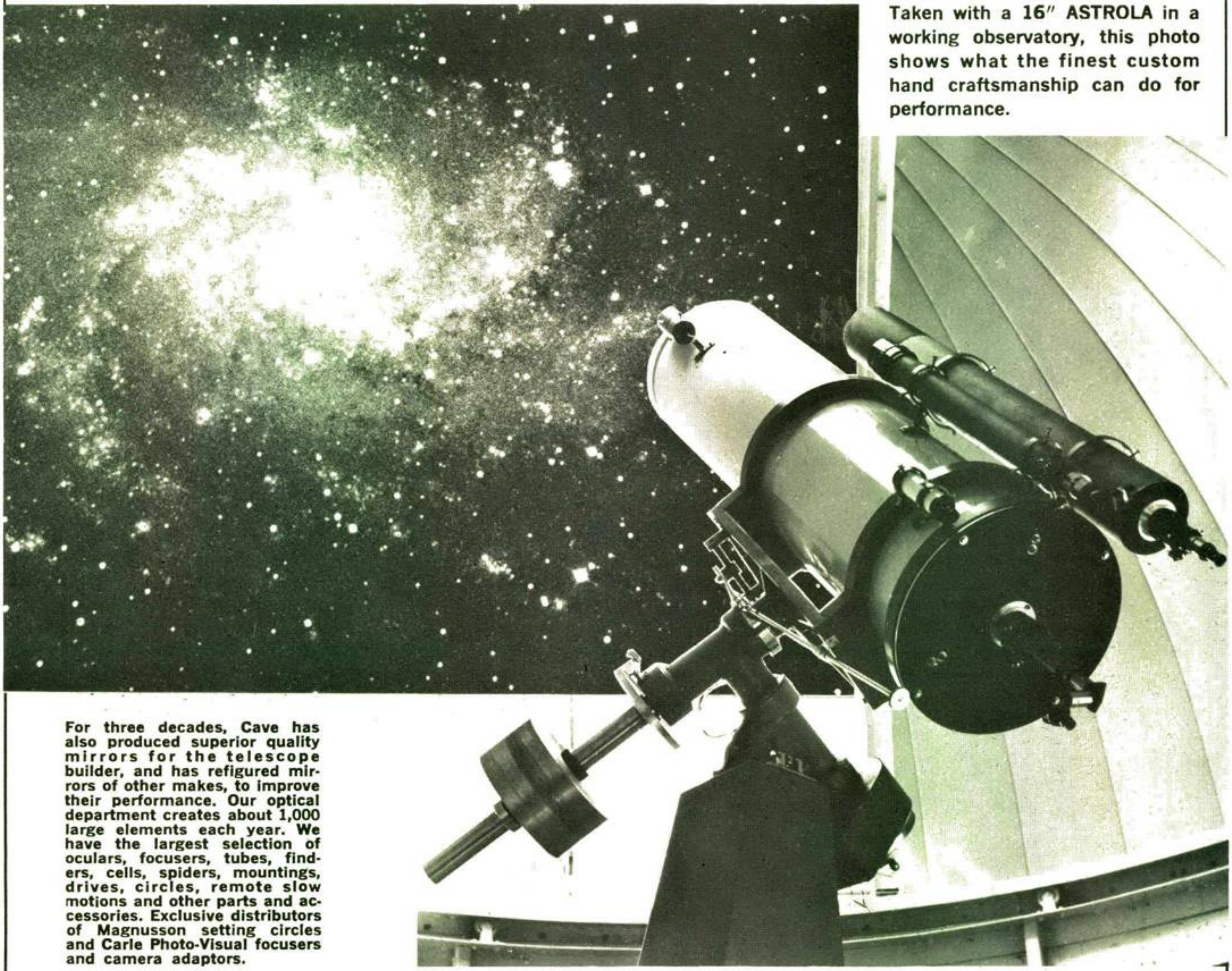

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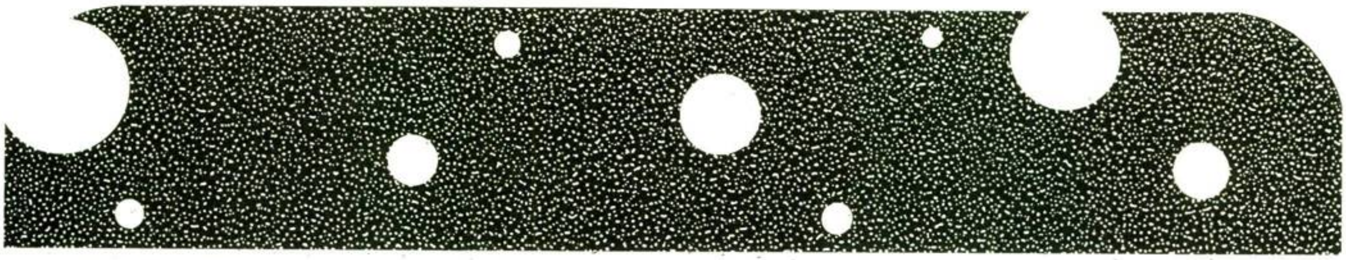


STELLAR FRONTIERS

Planetary Nebulae, Part 2

Cosmic Neon Lights

by

David Darling

All stars are born, grow old, and die. Some, if they're massive enough, end in a blaze of glory as a stupendous, galaxy-rivaling supernova. Others, the lightweight energy-misers, fade imperceptibly over vast time scales (see "Red Dwarf Stars," ASTRONOMY, July 1978). Stars like the Sun, though, or those somewhat more massive (up to around 4 solar masses), take an intermediate path: a highly significant one, as it turns out, for the Galaxy as a whole. They blow off a substantial portion of their material — typically around one-fifth of the total — into space as a planetary nebula.

Last month we looked at some probable mass-loss mechanisms in planetaries. Astronomers today are more and more convinced that the nebular shell is released over a period of several thousand years as a kind of intense "stellar wind." This is quite different from the older notion of a single explosion in which the star's hydrogen atmosphere is cleanly ripped away from the intensely hot, collapsing core. The basic mechanisms for mass-loss from the parent stars, though, are essentially the same in either case.

Dynamical instabilities, helped by growing radiation pressure in the cool, neutral outer layers of red giants, are known to be capable of causing nebular ejection. If these instabilities are periodically checked before they can grow too large, only a tiny amount of star matter leaks away before the pulsing hydrogen envelope falls back towards the core. The single-ejection model suggests that the instability, once it has begun, must continue until all of the upper layers have escaped into space.

What's the fate of this freed stellar atmosphere? What are the processes happening locally within the nebula, and, on a wider scale, what's the galactic significance of planetaries?

First, let's focus right in on the fascinating events taking place within one of these nebulae. Whatever forces cause the ejection, the end result is a cloud of hot, luminous gas around a small, dense remnant star. It's a perfect natural astrophysical laboratory with all the familiar laws of physics — but in unfamiliar guises.

Expansion speeds for planetaries are on the order of 15 to 30 kilometers per second. That's pretty low when you make a comparison with novae (in which around one-thousandth of a solar mass is ejected at 1000 km per second) or supernovae (several solar masses are hurled spacewards at one-tenth light-speed). Even rapidly expanding planetary nebulae, like the curious double-shelled Eskimo Nebula (NGC-2393), barely touch 50 km per second.

An important question is just how does a planetary nebula become visible in the first place? Right after leaving the parent star it was a fairly cool, neutral shell of gas — the escaped atmosphere of a bloated, unstable red giant. Continuing thermal expansion after its ejection would tend to force its temperature even lower: down towards the few degrees absolute of interstellar space. What's the factor we're overlooking?

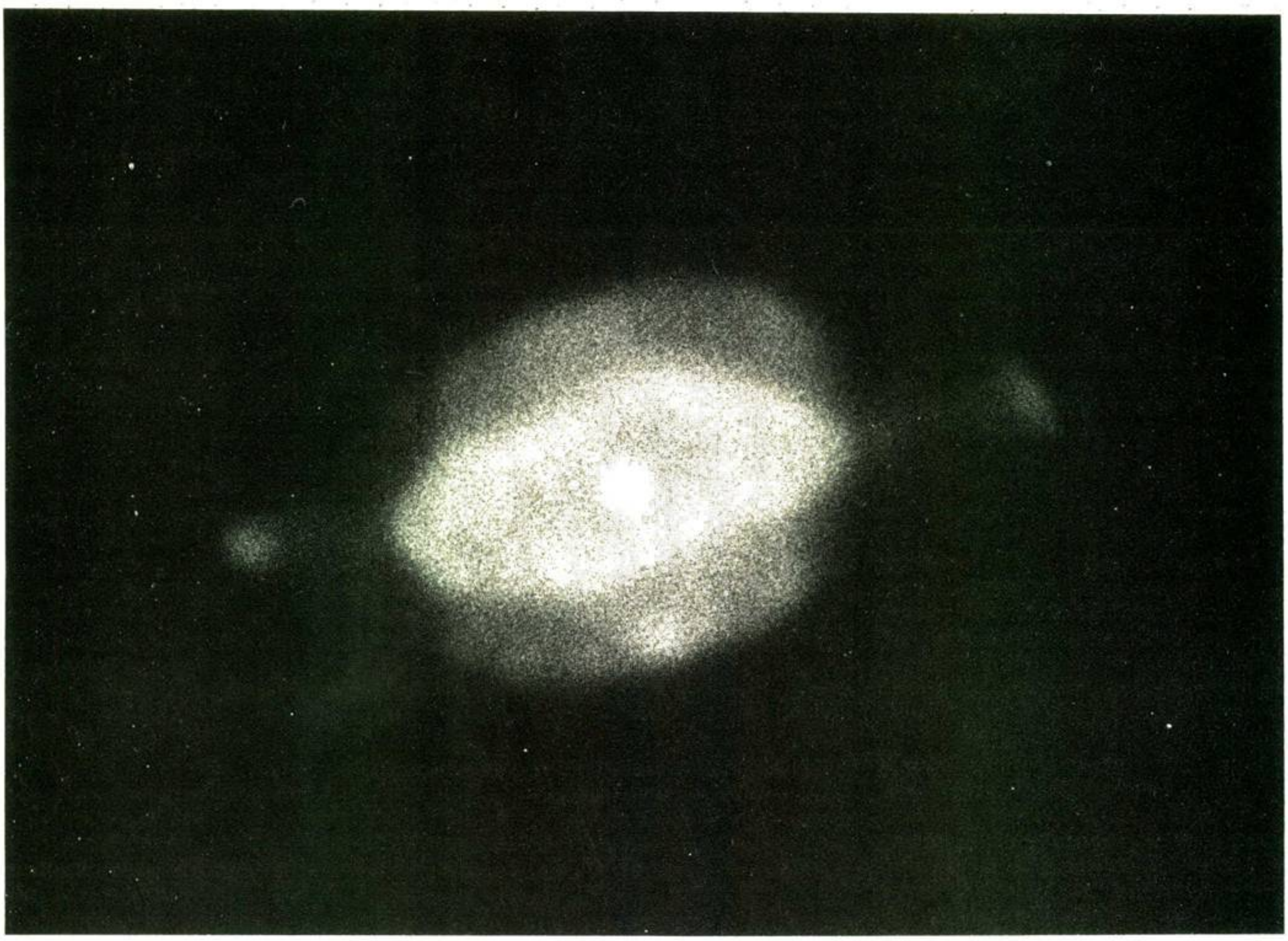
Think of it this way. You get a letter in the mail saying that a rich uncle has left you a large spherical cloud of gas in a region of space some thousand light-years from the Sun. It's very cool (a little above absolute zero), very tenuous (no more than ten thousand atoms per cubic centimeter), and is mostly hydrogen. It's been in the family for years, just gathering interstellar dust . . . .

You wonder why that cool, tenuous cloud should be dark and invisible. Why is your nebula so different from those bright, shining ones like the Ring and the Helix? Even the Orion Nebula, not a planetary at all, glows beautifully.

For some reason these others shine strongly at visible wavelengths. Just what have they got that your heirloom hasn't? *Stars*! All so-called "emission" nebulae are intimately associated with stars — specifically, very hot stars. Sometimes, as with the fantastic Orion Nebula and other objects of its genre (the "diffuse" nebulae), these hot stars are young and massive, having just formed from part of the very stuff which they're now making visible. In the case of the planetaries, the nebular powerhouses are the burnt-out cores of stars whose only remaining thermonuclear fuel was extravagantly cast off as a vast gas cloud.

You're now a step nearer the solution of your problem. But, being an enterprising individual, you're not content merely to embed a suitably hot star into your nebula, sit back, and watch the show. You ask: Just what processes cause an emission nebula to shine and what makes up the spectrum of a typical planetary? What are the main spectral components?

It very often happens that conditions we'd find difficult or impossible to reproduce here on Earth are commonplace in the universe at large, and so it is with planetaries. No terrestrial



This photograph by the Cerro Tololo Inter-American Observatory shows clearly how the famous Saturn Nebula in Aquarius (NGC-7009) got its name. The ringlike projections, however, are not visible in small telescopes. Although its distance is estimated at about 1430 light-years, a third less than that of the Ring Nebula (M-57), the Saturn is only half the apparent size of the Ring. This may mean that the Saturn Nebula is a younger planetary which has not yet expanded as much. Photo courtesy of the Kitt Peak National Observatory.

laboratory can adequately simulate the environment of one of these nebulae: a highly rarefied mix of atoms and ions, mainly hydrogen, bathed in an intense stream of high-energy ultraviolet radiation. We shouldn't be too surprised at all if unfamiliar spectra are produced.

Spectral lines are as useful in identifying elements as fingerprints are in tracking down criminals. There's no place for doubt: Each element, and also the particular ionic species you get by stripping away its outer electrons, has its own peculiar set of "spectral fingerprints."

The lines we're interested in when talking about planetaries are emission lines, which are bright, unlike the dark absorption lines. Emission lines are formed either by electrons recombining with ions or by electrons tumbling down through the energy levels within an atom or ion.

The process works something like this: in soaking up the intense ultraviolet from the central star, atoms become stripped of one or more of their outer electrons in a process called ionization. Then, upon recombination, each ionic type gives rise to its own unique "recombination spectrum." Only hydrogen and helium ions are sufficiently common to give bright recombination lines, because, as you'd expect, the strength of these lines is very closely linked to the numbers of the ions causing them.

Here's a good place to pause and ponder an effect called "ionization stratification." It refers to the way in which the degree of ionization of various elements changes from the innermost to the outermost parts of a planetary nebula. Close to the central star, even helium — the most difficult of all substances to strip electrons from — may be singly (and in rare cases, doubly) ionized. Trace amounts of iron, carbon, neon, and the more common oxygen and nitrogen, stripped of several electrons, swim through the inner boundary, the inner stratum, of the nebula. Farther out, where fewer of the really energetic stellar photons penetrate, helium exists in the neutral state, doubly ionized oxygen makes way for the singly ionized variety, and the general extent to which electron stripping takes place falls off. This stratification effect starts to make sense when you examine photos of nebulae taken at different wavelengths. M-57, the Ring Nebula, dramatically illustrates the effect: ions of elements in their various states actively radiate their characteristic radiations from quite distinct regions within the nebula at various distances from its center.

So far it seems pretty clear-cut. But when astronomers first looked at the spectra of planetaries (and of emission nebulae in general) they found a mystery. The strongest emission lines were not those of hydrogen, or even helium (the second most abundant element). Dominating the spectrum was a pair of green lines with a wavelength of about 5000 Angstroms, the brightest of a whole mob of unfamiliar components. All the anticipated recombination lines were there too: hydrogen, helium, and even the very faint ones of the heavier elements. But *what* was causing those extraordinarily bright unidentified lines?

By 1927, astronomers had been driven to the explanation that a totally new element, which they called, logically enough, "nebulium," was the source of the odd spectral features. So when the true solution was found that year it came as a great relief to discover that nothing so radical as an addition to the periodic table of elements was required. Nebulium hit the junk pile of failed hypotheses as the familiar names of oxygen, nitrogen, sulfur, and others, came through to provide the answer to the mystery. How?

Wait a moment. Back up. We're not talking about the good old Earth where heavy elements like oxygen and nitrogen are common. Within a nebula, hydrogen atoms dominate, helium atoms are significant, and the rest are quite few and far between. Oxygen, for instance — one of the more common of the "heavy" elements — is about a thousand times rarer than hydrogen. Just how, then, are the strange bright lines produced?

The answer lies with a process termed "collisional excitation." That simply means the shifting of bound electrons into higher, more energetic states by electron-ion collisions. Galaxywide, it's a pretty significant process, and its more extreme cousin, collisional ionization (where electrons are knocked out of their atoms altogether) is prominent in supernovae remnants.

This is a wholly different process from the "excitation" of electrons by the absorption of stellar ultraviolet radiation. The distinction is sharp. The average free electron, wandering through a nebula, has a lot less energy than an ultraviolet photon speeding outward from the hot central star. The end result is that whereas ultraviolet absorptions can singly or multiply ionize any atom within the nebula (with the possible exception of helium), electron-ion collisions can cause only small rearrangements of an ion's electronic structure. Maybe it's surprising to find, then, that this low-energy process — collisional excitation — is one of the most vital to the entire make-up and appearance of a planetary nebula.

Thinly scattered though they are, it's those ions of oxygen, nitrogen, and other elements heavier than helium which play the key role here. They're the ones which have the all-important, low-lying energy levels into which electrons are raised during collisional excitation.

In the low-density, high-radiation environment of the nebula — exotic and impossible to recreate in a laboratory on Earth — they undergo certain unusual electronic energy shifts, called "forbidden transitions." The intense green line-doublet at 5000 A is a forbidden transition of doubly ionized oxygen. Other, less bright, lines of singly ionized oxygen (in the ultraviolet), doubly ionized nitrogen (in the red), and so on, are scattered across the spectrum of every planetary nebula.

Radiation escaping from planetaries in forbidden lines effectively carries heat away from the nebula. Indeed, without the cooling process of collisional excitation resulting in forbidden line emission, planetary nebulae would get extraordinarily hot. They'd reach more like 100,000° Celsius, the average nebular temperature observed. Forbidden-line cooling is the planetaries' thermostat.

Complex equations express the delicate thermal energy balance of nebulae, but what they say is essentially simple: there's only one way you can heat up a planetary, but there are many ways you can cool it down. The heating has to be done by ionizing atoms, almost all either hydrogen or helium, with stellar ultraviolet light. Cooling is achieved mainly by lowering the average electron energy during collisional excitation and subsequent forbidden-line emission. Recombination-line cooling helps too, along with some other less important processes.

So far we've focused on a really narrow band of the electromagnetic spectrum — the visible band. Let's probe further and see what's happening at the other wavelengths we receive from planetaries.

Infrared observations are especially interesting. They've shown that tiny grains of dust, probably graphite interspersed with various silicates, must have condensed out during the early phases of nebular expansion. The already cool upper layers of the ballooning parent star would have cooled even further immediately following the ejection, making conditions favorable for grain formation. Molecules, too, notably carbon monoxide, may have formed at this time. The infant planetary NGC-7027 (in Cygnus), a very compact object, seems to be made up from an interesting stew of dust, molecules, and gas in various stages of ionization.

At even longer wavelengths, radio telescopes give us glimpses of structural detail in planetaries often obscured by thick clouds of dust. We're able to pull out much useful information here because the very same hot, ionized gas which is pouring out visible light is also active in the radio region. Radio synthesis maps built up from observations on powerful instruments like the VLA (Very Large Array) in Socorro, New Mexico, are studied alongside high-resolution photographs of the same objects. Astronomers have made enormous leaps in their knowledge of the electron temperatures, densities, and dust distributions of planetaries in this way.

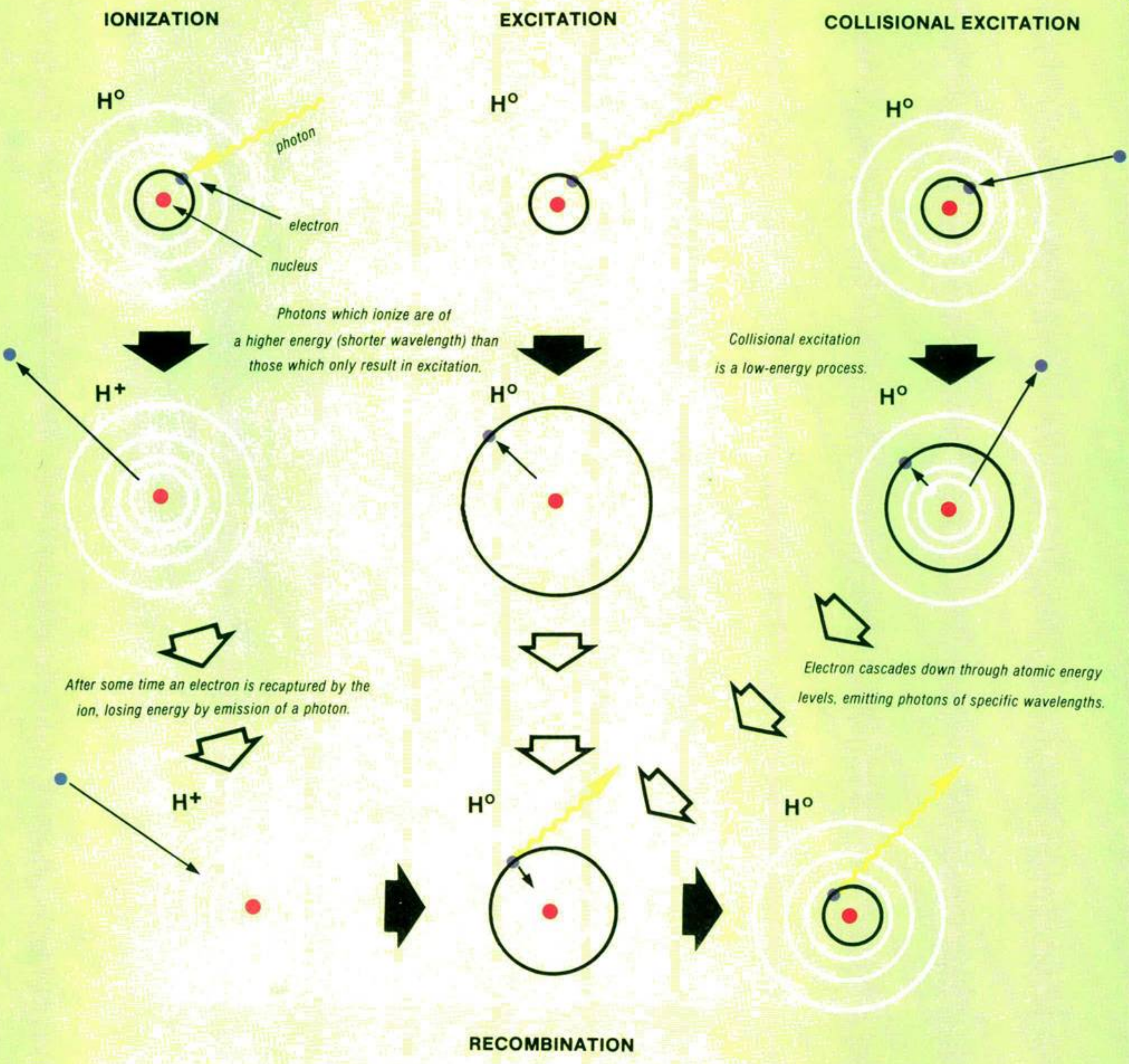
Spaceborne ultraviolet detectors are widening our understanding of the hot blue cores found at the heart of planetary nebulae. Typically, these small, dense stars are speeding rapidly in their evolution toward the white dwarf stage. We think we have a pretty good idea of the processes which have led up to their present condition, yet we still find surprises.

Take Abell 63. It's very faint and was only recognized as a true planetary for the first time in 1966. The central star was identified with the known variable UU Sagittae. Now the odd thing is this: UU Sag turns out to be a binary star system. Two stars, a small hot O-type sub-dwarf and a larger cool K-type dwarf orbit around each other with a period of just over 11 hours. It would certainly make a fascinating sight close up. The side of the K-type star facing its hotter companion is heated to around 10,000 degrees Celsius — the cooler star must be orange on one side and white on the other. There are other examples of binaries close to the centers of planetaries. NGC-3132, a spectacular planetary not seen from northern latitudes, contains a stellar duet. The more conspicuous component, HD 87892, is offset a little from the exact center of the object. Its spectral class, A, makes it too cool to be the true nucleus and astronomers searched for a hotter, but fainter, companion. They found it: an extremely blue star, around 100,000 degrees Celsius surface temperature and pouring out over one hundred times more energy than the Sun — most of it in the ultraviolet. And all this from a star about the size of Neptune.

We don't fully understand why binary systems are found within planetary nebulae; it adds a complication to our current view of stellar evolution. We're faced with the concept that although novae, with a much smaller mass loss, are always associated in binaries, planetary nebulae can apparently result from a wider range of stellar configurations.

Whatever neighbors a star may or may not have, only a particular type of star is likely to go through the planetary nebula stage — not the massive, luminous objects found in the dusty spiral arms of the Galaxy, nor the ancient, metal-deficient stars of the globular clusters or galactic halo. As a candidate for the development of a planetary, we need look no further than our own Sun.

Many stars, of which the Sun is one, are not concentrated in the spiral arms like the so-called Population I type objects. Neither do they swing well out from the galactic plane in those huge sweeping orbits characteristic of the old extreme Population II stars of the galactic halo. The objects we're

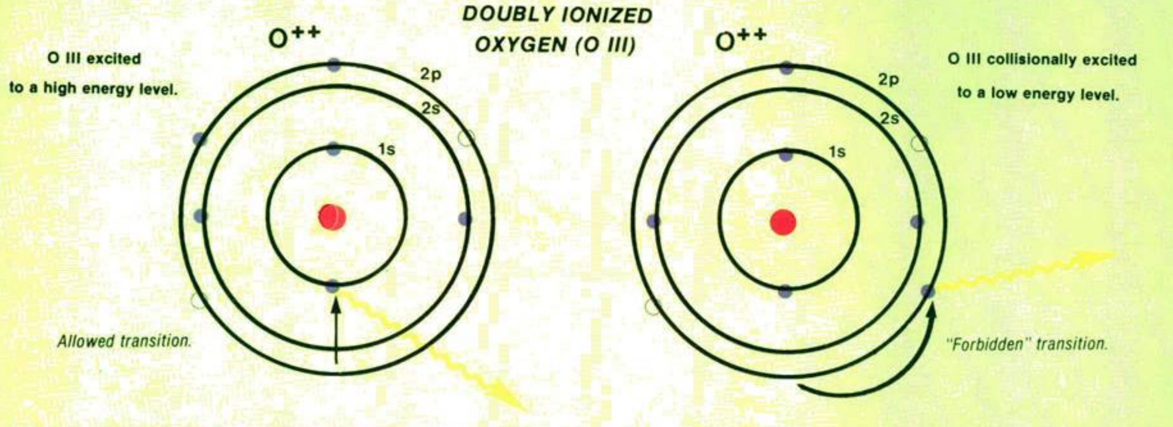

IONIZATION
EXCITATION
COLLISIONAL EXCITATION
H^0
photon
electron
nucleus
H^+
RECOMBINATION

Photons which ionize are of a higher energy (shorter wavelength) than those which only result in excitation.

Collisional excitation is a low-energy process.

After some time an electron is recaptured by the ion, losing energy by emission of a photon.

Electron cascades down through atomic energy levels, emitting photons of specific wavelengths.


DOUBLY IONIZED OXYGEN (O III)
O^{++}
2p
2s
1s

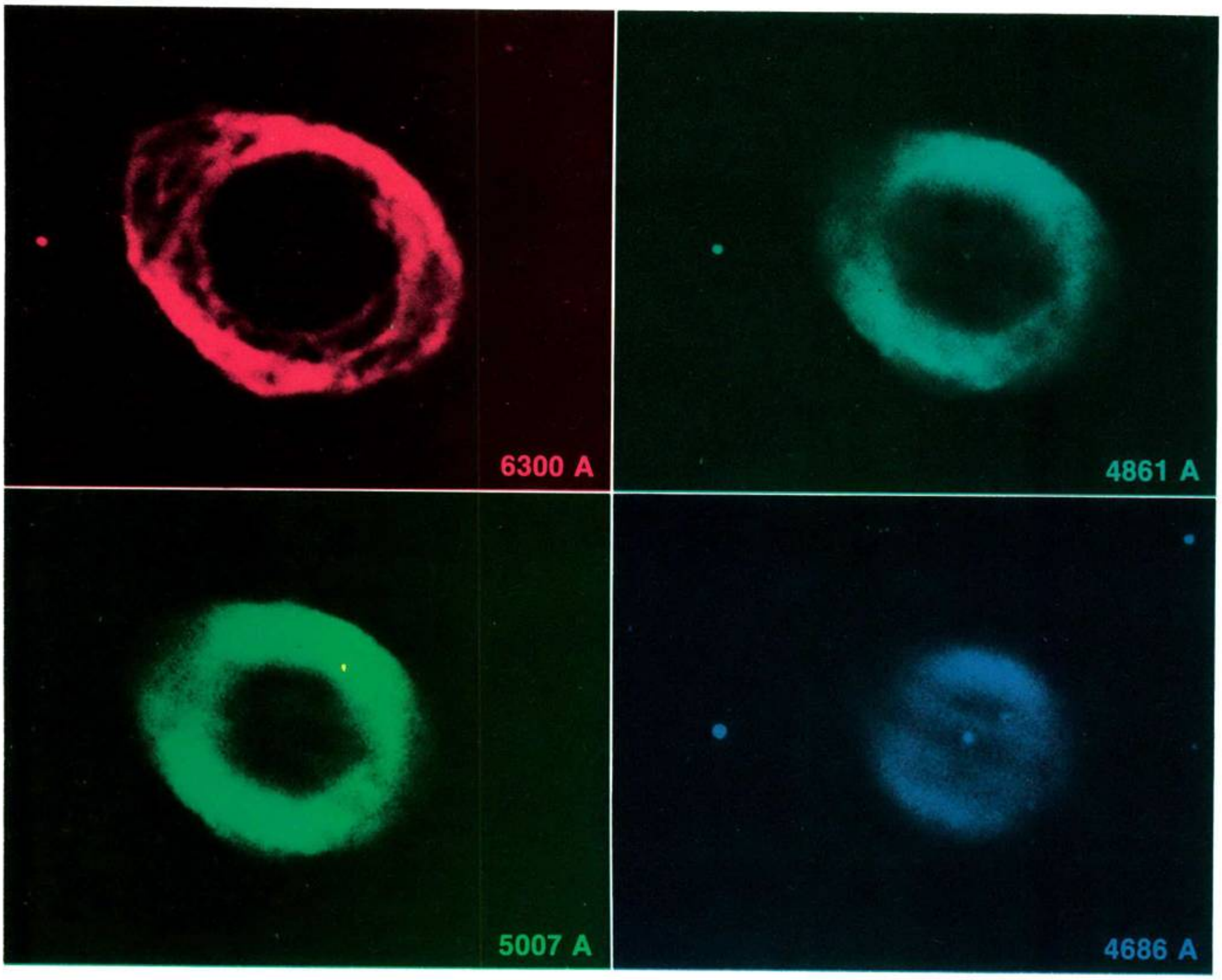
O III excited to a high energy level.

O III collisionally excited to a low energy level.

Allowed transition.

"Forbidden" transition.

Atoms of doubly ionized oxygen (oxygen which has lost two of its electrons) are responsible for the strong emission lines of planetary nebulae around 5000 A. Collisional excitation causes a slight increase in the energy level of O III. The probability of a drop to a lower energy level is small, and therefore takes a long time to occur. In an Earth laboratory, the ion is not left undisturbed long enough for such a transition to take place, so it is said to be "forbidden." But in the rarefied vacuum of nebular gas there is plenty of time for "forbidden" transitions to occur, giving rise to the observed "forbidden" emission lines.



Photographed at four different wavelengths of visible light, the Ring Nebula in Lyra (M-57) reveals its complex structure. Atoms in different states of ionization at various distances from the central star emit light at different wavelengths. The bright green light emitted at about 5000 Angstroms is due to atoms of oxygen which have each lost two electrons. The red light (6300 A) comes principally from the cooler outer layers of the expanding nebula. Closer in, the gas cloud is considerably excited by the intense radiation of the central star, and glows with an eerie blue light (4686 A). The hot central star itself shows up most clearly at the high energy blue end of the spectrum(4686 A).

interested in here show a typical disk distribution, moving in that region of the galaxy inhabited by evolved stars like the RR Lyrae variables and the novae.

The known presence of a planetary nebula within a globular cluster (M-40) is a curious anomaly, one which points to at least some of these objects belonging to extreme Population II. Generally, planetaries lie within a few degrees of the galactic plane, no farther out of it than around 500 light-years, and are fairly well-concentrated toward the center of the galaxy. Along with supernovae remnants, pulsars and novae, they earn their categorization as members of the old disk population.

Planetary nebulae are a popular class of objects for amateur observation. If this two-part series on the origins and characteristics of planetary nebulae has whetted your appetite for a look at the real thing through your telescope, see "Observing Planetary Nebulae" in ASTRONOMY, August 1977, for an introduction to this fascinating field and a table of the finest planetaries.

How many planetaries are there in the Galaxy today? Around 1000 have been positively identified, but that's only a small fraction of the total galactic population. With increasing distance from the Sun, planetaries, of course, appear smaller and fainter. Interstellar dust, particularly thick in the direction of the galactic center (where we'd expect to find the richest harvests of nebulae), obscures the vision of even the largest optical telescopes. Infrared and radio instruments fare better in this respect, since the longer wavelengths are much less affected by absorption from dust.

Based on our current knowledge of distribution and observed numbers, astronomers come up with a figure in the range of 25,000 to 50,000. What can we deduce from that? First, that around 5 suns' worth of star matter is pumped back into the interstellar medium every year from planetaries. That makes a great deal of material for the formation of new stars. Second, probably over half the stars we can see in the night sky will pass through the planetary nebula phase in their late evolution. The formation of a planetary nebula is obviously a significant aspect of stellar life in the galaxy. Our Sun will ultimately go through this — in around five billion years.

David Darling received his doctorate from the University of Manchester (England). For his thesis topic he studied the dynamics of multi-envelope planetary nebulae. He is currently working on a comprehensive source book dealing with unusual and peripheral scientific phenomena.

ASTRO-NEWS

Latest News From the World of Astronomy

NASA Abandons Plans to Save Skylab

Skylab, the huge orbiting space laboratory launched by NASA, was last occupied by astronauts in early 1974. Since then, its orbit has degenerated faster than originally predicted — partially because of increased sunspot activity — and it became evident some time ago that it wouldn't remain in orbit until 1983 as planned so that Space Shuttle astronauts could visit it and boost it into a higher orbit.

Early in 1978, NASA commenced a series of maneuvers designed to prolong the orbital life of the 85 ton satellite station in hopes that a Space Shuttle could still reach it in time. Among these maneuvers was one designed to minimize atmospheric drag by orienting the structure so that its narrowest cross-section remained perpendicular to its line of motion throughout each orbit.

Later calculations, however, led NASA scientists to conclude that Skylab couldn't be saved. Sunspot activity has been exceeding even the revised estimates, while the Shuttle schedule has been subjected to several delays. Furthermore, the cost of constantly controlling the station to maintain its orientation, and of developing a special booster to send it into a higher orbit, was becoming excessive. There was also doubt whether power components aboard Skylab would last long enough to enable the stabilizing maneuvers to continue for the necessary time.

So late last year NASA abandoned its plans to save the orbiting laboratory. The agency estimated that it would hurtle down to Earth sometime this summer. The re-entry of such a massive object would probably scatter metal debris over a path perhaps 4000 miles long and 50 miles wide. The impact zone will lie between latitude 50°N and 50°S, the band spanned by Skylab's orbit, but beyond that, it's impossible to predict the location very much in advance. Three-fourths of the possible impact area is ocean.

Nevertheless, NASA contends that the chances of serious damage or injury resulting from Skylab's re-entry are less than that of being struck by a meteorite. The agency argues that much of Skylab's 85 ton bulk will burn up in the atmosphere, though it admits that some substantial pieces, including one weighing about 2½ tons, are likely to reach the ground, perhaps with a velocity of several hundred feet per second.

NASA's decision was approved personally by President Carter, but a flood of criticism and protests followed the announcement. Most have focused on the supposed danger of large hunks of debris striking populated areas, even though the chances of this are extremely small. But some have criticized the government's lack of advance planning in allowing the loss of such an important piece of space hardware to come to pass.

In hopes of minimizing any possible danger at the time of re-entry, NASA has now purposely placed Skylab into a high-drag attitude which will cause it to fall sooner — perhaps as soon as May. The early re-entry increases the chances that the station will have sufficient power and operative systems to enable some control to be exercised over the projected impact point. But NASA is not yet sure that such control will be possible in any case because of the number of unknown factors involved in the re-entry.

Contingency plans have been worked out involving four government agencies in addition to NASA if Skylab debris should come down in populated areas. The four include the State, Defense, and Justice Departments along with the Federal Preparedness Agency.

Cosmic Microwave Radiation May Not Be Due to Big Bang

The discovery of a microwave background emission coming from all directions in space has traditionally been interpreted as an "echo" of the Big Bang which gave rise to the universe. Seen as a confirmation of this theory of the origin of the universe, the detection also earned a Nobel prize for its discoverers.

Now Martin J. Rees of the Institute of Astronomy at the University of Cambridge (England) has suggested a mechanism which — apart from the Big Bang itself — could account for the observed thermal radiation of about 2.7 Kelvin. His model paints a picture of the universe, at an age of one to ten million years, as being densely packed with huge, super-luminous stars imbedded in a thick obscuring cloud of dust and gas.

Writing in **Nature**, Rees suggests that the dominant form of mass in our present universe may be the dark, dead remnants of massive or super-massive stars which formed when the universe was less than a million years old. Such energetic, highly luminous stars would have had a lifetime not much greater than ten million years or so, and would have died out before the galaxies assembled as recognizable units. But his calculations show that they could have generated enough radiation to account for the observed microwave background, assuming the presence of enough heavy elements, molecules, and dust at that period to absorb the radiation and become heated to a temperature of a few hundred degrees. Subsequent expansion of the universe would have red-shifted the thermal radiation to the present 2.7 K level.

One advantage of Rees' scenario is that it manages to account for the observed ratio of photons to heavy particles in the universe. The standard

MICROWAVE *continued on page 55*

Infrared Astronomy Advances in Wyoming

A small university in a state not known for much advanced astronomical research now has the world's largest operational infrared telescope. A group of five University of Wyoming astronomers, headed by Robert Gehrz and John Hackwell, have been studying the infrared universe with a 92-inch (2.3 meter) Cassegrain reflector since November 1977. The telescope rests on Jelm Mountain, a 9,656 foot peak 35 miles southwest of the university campus in Laramie.

This telescope is the first of its kind to usher in a new era of infrared astronomy. The pioneering Jelm Mountain telescope will be joined this year by the United Kingdom's 3.8 meter and NASA's 3.1 meter instruments on Mauna Kea in Hawaii. These three telescopes are the response to the National Science Foundation's (NSF) request for the construction of large aperture infrared telescopes.

The NSF funded 40% of the cost and the state of Wyoming funded the rest. The total cost of the installation was $1.6 million.

With such a telescope, the astronomers in Wyoming can observe infrared radiation in the wavelength range of 1 to 1,000 microns (10,000 angstroms to 1 millimeter). This radiation seldom penetrates Earth's atmosphere because water vapor readily absorbs it. With optical seeing conditions rated equal to Mauna Kea in Hawaii and Cerro Tololo in Chile, plus very dry air, the Jelm Mountain infrared detector is "seeing" a part of the universe previously only glimpsed briefly by rocket-borne instruments.

Although Gehrz and associates are studying known objects such as planetary nebulae, the galactic core, quasars, and planetary atmospheres, they are also studying stars that emit no visible or short wave radiation. They are called *cocoon stars* and are either very young proto-stars or ancient stars in their last death-gasps.

Gehrz, in a recent interview at his University of Wyoming office, talked about these newly discovered stars. "A cocoon star is any star surrounded by a circumstellar sphere of dense but fine dust particles. We've discovered with IR spectroscopy that the dust is much like terrestrial soil (silicates) or graphite with some water ice, acetylene, carbon monoxide, and other organic compounds mixed in. Due to the opacity of these shells of dust, all the central star's energy is absorbed. The absorbed energy heats the dust to about 300 to 400 degrees Kelvin. It is this black-body heat radiation that we are now able to study on a 24-hour-a-day basis," Gehrz commented.

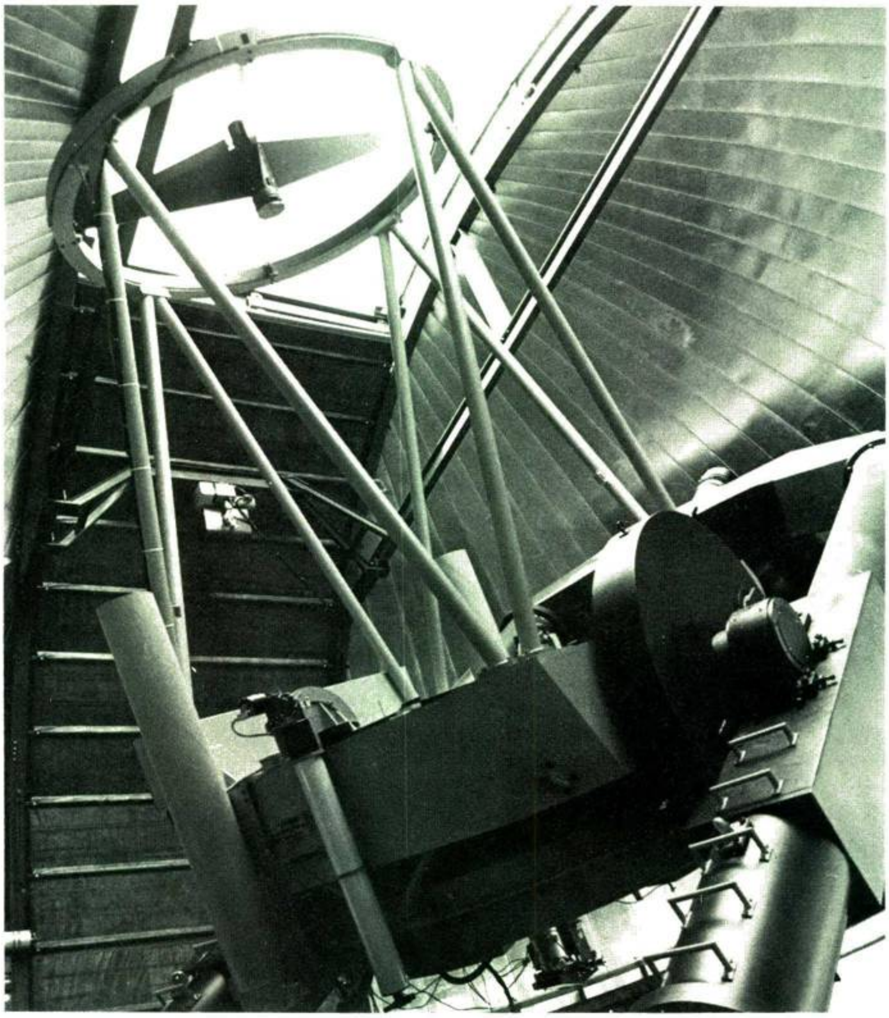
Coccon stars have been suspected in the Orion Nebula for many years. Here, deep inside the ionized-hydrogen regions, the Wyoming researchers are studying infrared stars that may have been emitting intense heat for only 2000 years. Infrared studies of such young proto-suns will add very important knowledge to the study of stellar evolution.

On the other end of a star's lifetime is found another type of cocoon star. These ancient stars could be called *coffin stars* because the dense surrounding shell of dust is the result of the last gasps of the dying central star. Gehrz and Hackwell have discovered that some of these cocoon stars are surrounded by fine graphite particles, and thus are called *carbon stars.*

One of the first confirmed IR carbon stars is designated CRL 3099. (CRL stands for the Air Force Cambridge Research Laboratory). The CRL sent a rocket probe of IR instruments on a suborbital flight in 1974 to get a baseline look at bright IR sources.

Gehrz, Hackwell, and D. Briotta reported in the **Astrophysical Journal** that the shell is about 10 a.u.s in diameter and emits IR radiation at about 360° Kelvin. "There is little doubt that this carbon star represents a post red-giant stage in stellar evolution. It isn't necessarily an old star in terms of the age of the universe but CRL 3099 lies 8,000 light-years above the galactic plane, thus placing it morphologically among the oldest stars in the Galaxy," said Gehrz.

INFRARED *continued on page 55*



The 92-inch (234 cm) telescope of the University of Wyoming shown above is the first of a series of large land-based infrared telescopes. The f/2.1 Cassegrain telescope has a special thin mirror to save weight, and is controlled by a computer. Located on Jelm Mountain in Wyoming, the instrument observes the range of wavelengths from 1 to 10,000 microns. Photograph by Robert D. Gehrz of the University of Wyoming.

INFRARED

continued from page 54

CRL 3099 was also found to be a Mira-type (long-period) variable with a range of 4.7 to 3 magnitudes depending on the IR wavelength studied. The authors presumed in their paper that the infrared variations represent changes in the luminous output of the central star which are mirrored by the thermal emission of the surrounding circumstellar shell. These large-amplitude photospheric pulsations are characterized by the mechanical dissipation of large amounts of energy. The result is the ejection of a dense shell of fine graphite dust particles. In order for such a carbon star to disappear optically, only a small fraction of the mass of a typical carbon star must be blown off. They suggest that objects like CRL 3099 could be a major source of interstellar graphite.

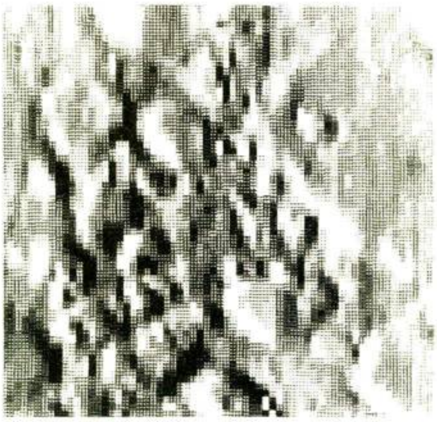
The Jelm Mountain astronomers are presently keeping a close watch on CRL 3099's variability. In order to confirm a Mira-like cycle, at least one year of observations is necessary.

The Jelm Mountain telescope is a fine example of the most advanced techniques in construction. The guidance of the telescope and the 45-foot dome is a fully automatic operation under the control of a computer. The astronomer is housed in a carpeted and heated control room. The computer uses a disk memory system preprogrammed to follow preselected objects. All incoming data are automatically stored. The control room also houses a television status-display screen, a printer, and a graphics terminal. A backup computer is available if the primary system fails. In the first 120 days of operation, there was no "down time" on the computer, however.

Eight times a second, the tracking of the telescope is automatically updated. Because of this, according to Gehrz, the accuracy of aiming is among the best in the world for telescopes of similar size.

The primary mirror is figured to optical accuracy, and therefore can be used for both optical and IR observation. The 92-inch primary is impressive in two ways — it is very lightweight and very "fast". This allows a short tube and lightweight construction. The mirror is over a ton and a half lighter than a similar conventional mirror. The weight was saved by making the mirror very thin. The outer edge is only 9 inches thick and the center 6½ inches thick. The primary is also unusually fast at f/2.1. For comparison, the Hale 200" reflector is f/3.3 and the 158" Kitt Peak (Arizona) reflector is f/2.7.

One of the key elements in IR telescopes is the ability to rapidly "wobble" the secondary mirror. The wobble effect flashes the reflected radiation intermittently on the detectors through the 7" hole through the primary of this Cassegrainian telescope. This wobble automatically scans an observing field of 3½ seconds of arc from 1 to 40 times a second. This allows a rapid comparison between the background IR radiation and the sources of IR under study. The background radiation can be several million times greater than the IR object. Once the background is automatically eliminated, an accurate IR "picture" emerges, revealing for the first time the cocoon stars and other IR sources.



This photograph of the Moon was taken by the scanning infrared telescope at the University of Wyoming and reconstructed by a computer. The scan was made at a wavelength of 10 microns (100,000 Angstroms) and covers a square area three minutes of arc on a side. The size of each picture element (or "pixel"), and hence the resolution of the image, is three seconds of arc. The dark areas are the brightest and the light areas the faintest, so the image is in effect a negative. A portion of the rim of Tycho appears at bottom center, with the crater Deslandres at upper right and part of the crater Pitatus at top center. In the upper left quarter of the picture the craters Wurzelbauer (left) and Gauricus are clearly outlined. Photograph by G.L. Grasdalen of the University of Wyoming.

Another key factor in the IR telescope is the detector array itself. It is actually a super-sensitive thermometer capable of taking the temperature of objects up to 5 billion light-years away!

The heart of the detectors are 6 gallium-doped germanium semiconductors. These 6 chips are so sensitive they must be cooled to a very cold temperature of only 1° K. This supercold environment (only 1° above absolute zero) virtually eliminates any unwanted heat energy that would mask the feeble heat waves from distant point sources of IR. The gallium chips were developed by Gehrz and Hackwell.

The liquid helium needed for the very cold cryogenic environment is supplied by the University of Wyoming's physics department. The shop and low temperature facilities were developed at Laramie specifically for the IR telescope. The black baffles used in telescopes to trap stray light are also cooled by liquid helium in order to prevent stray IR radiation.

Gehrz was asked about the next step in IR astronomy. "Beyond the two IR telescopes in Hawaii and ours will be two IR satellites scheduled for launch in the 1980s. The first will be the IR astronomical satellite (IRAS) scheduled for a 1981 launch. In the mid-1980s the cooled Shuttle IR Telescope Facility (SIRTF) will be launched. SIRTF will offer an increase in sensitivity by a factor of a thousand. Thus the time for making a reading with precision will be decreased by a factor of a million," said Gehrz.

It will then be possible to probe the IR universe as deeply as optical and radio astronomers. Such a rapid development in just one decade is an amazing accomplishment for modern astronomy.

OOOPS!

Nebular Filters

Due to a production error in the diagram in "Nebular Filters" (March 1979 issue, page 53), the color background behind the diagram was printed backwards. The transmission curves and wavelength data shown are correct, but the colored background is incorrect. Because the nebular filter field is changing so rapidly, ASTRONOMY will run an update article on nebular filters in the June 1979 issue.

MICROWAVE

continued from page 53

Big Bang theory views this ratio as essentially random — it could have taken any of a wide range of values. But by ascribing the cosmic microwave radiation to calculable astrophysical processes taking place at a time later than the Big Bang itself, Rees is able to derive a specific value for the ratio — which is in accord with the observed value.

While Rees' mechanism for the origin of the background radiation does not at all contradict the Big Bang theory of the origin of the universe (in fact it assumes it), his proposal implies that the characteristics of this radiation don't tell us anything about conditions in the Big Bang itself, but rather reflect conditions in the universe at a later time. More careful and exact observations of the microwave spectrum could distinguish between the traditional theory and Rees' model of the origin of the cosmic microwave background.

Galactic Center Is Pictured

Two astronomers working at Hale Observatories have used scans of infrared radiation emanating from the center of our Galaxy to produce the first "picture" of the galactic nucleus. The picture gives a clear look at the mysterious galactic core, totally obscured by dust and gas at visible wavelengths, where intense radio and other emissions indicate the presence of some unknown, violent process.

In a separate set of observations, four other astronomers at Hale Observatories have also examined the galactic center at the particular wavelength of infrared emission that marks the ionized form of the gas neon. Their observations of this gas in the galactic center show that it is in rapid motion, but also indicate, surprisingly, that it is uniformly cool. The observations cover a region only about three light-years in diameter (roughly the distance from the Sun to the nearest star), but which is crowded with stars totaling millions of times the mass of the Sun.

The astronomers who produced the first picture of the galactic center are Eric E. Becklin, now at the Institute for Astronomy in Hawaii, and Gerry Neugebauer, professor of physics at Caltech. Their results were published in the **Publications of the Astronomical Society of the Pacific**.

While visible light is reduced about ten trillion times in its journey to Earth from the galactic center, infrared light is reduced only about tenfold, because it can penetrate better the interstellar dust clouds obscuring the nucleus.

The picture of the center, which also showed many bright foreground stars and patches due to intervening dust clouds, clearly revealed the dense core of stars in the galactic nucleus.

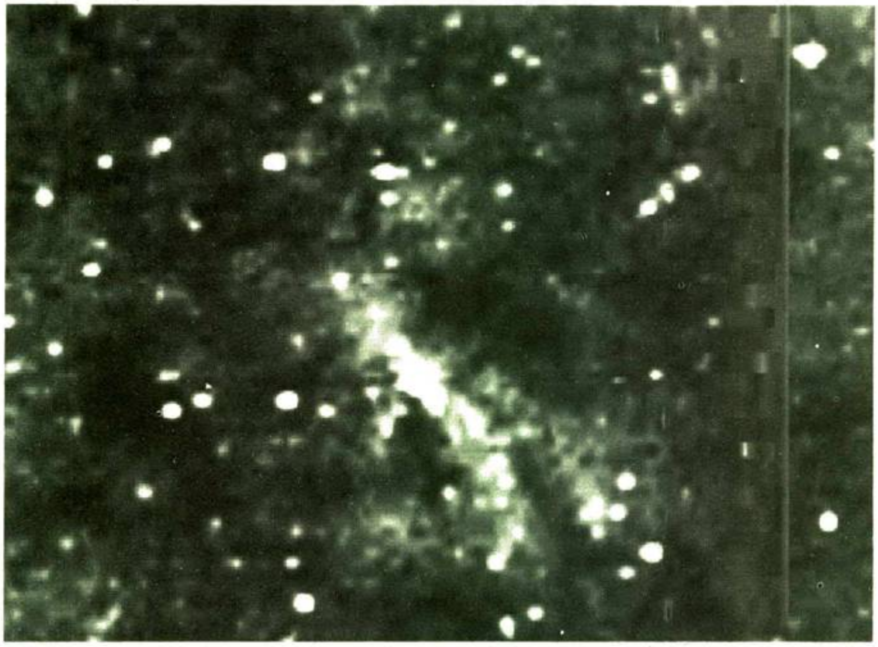
Other astronomers working at Hale Observatories have scanned the galactic center at an infrared wavelength of 12.8 microns. Radiation detected at this specific wavelength is due to emission by singly-ionized neon gas, that is, neon atoms which have had one electron stripped from them by heating or other energetic processes.

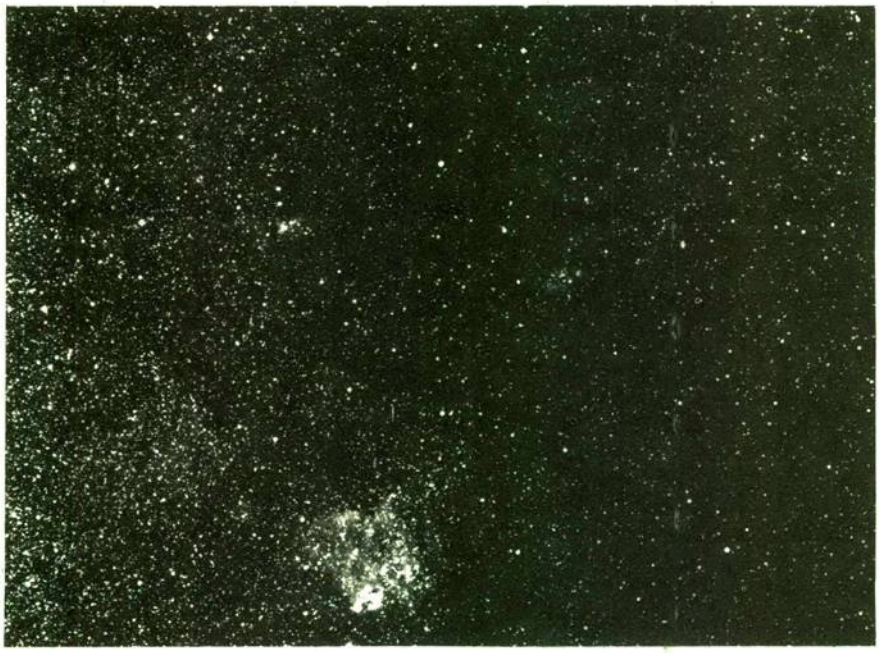
The scientists, John Lacy and Charles H. Townes of the University of California at Berkeley, Fred Baas of Leiden University in the Netherlands, and Thomas Geballe of Hale Observatories, published their results in the **Astrophysical Journal Letters**.

While the 2.2 micron scans by Becklin and Neugebauer revealed the infrared glow of the stars themselves, the 12.8 micron scans produced data on the distribution of ionized neon, telling us something about the temperatures and motion of interstellar gas near the galactic center.

Based on their observation of the gas motion, Lacy, Baas, Townes, and Geballe calculated that about eight million solar masses of material exist within a central region about three light-years in diameter. From Becklin and Neugebauer's picture, the researchers calculate that stars make up a significant fraction, if not most of this material. Despite the high concentration of stars, the galactic center is relatively cool, the scientists found. While singly-ionized neon was detected, no doubly- or triply-ionized

GALAXY *continued on page 57*





The top photograph shows the center of the Galaxy as seen at infrared wavelengths. The height of the image, produced on a television screen from a number of separate scans across the region, is just over one degree. The large bright spot at center is the highly dense concentration of stars in the galactic center. The pointlike bright objects scattered over the picture are probably foreground stars. The dark patches are probably dense interstellar clouds between our solar system and the galactic center. The bottom photograph shows the same area of the sky, but was taken with the 48-inch Schmidt telescope at Palomar Mountain. It is clear that the galactic center is totally obscured when viewed at visible wavelengths. Photographs courtesy of the California Institute of Technology.

GALAXY *continued from page 56*

elements were seen, which indicates that the gas in the galactic center is not being excited by any high-temperature objects (such as very hot stars). Such extreme heating, which is relatively common elsewhere, would have produced a more even mixture of singly-, doubly-, and triply-ionized elements.

Some astronomers believe that a supermassive black hole, containing several million suns' worth of matter collapsed to an extremely dense state (and exerting enormous gravitational pull), exists at the galactic center. The intense radiation from gas at the center, they theorize, is due to the energy released when matter falls into the hole and is consumed.

"While the evidence we've found for a uniformly cool galactic center does hint that a single massive object such as a black hole could be responsible for the energy emissions seen, the evidence for a black hole is still only indirect," said Geballe.

Our Galaxy, the Milky Way, is a flat spiral of over 100 billion stars about 100,000 light-years across and 2,000 light-years thick. The densest parts of the galaxy are contained within its nucleus, while our Sun lies out in the thin, more sparsely populated disk extending from the nucleus.

Uranus and Neptune Studied

Neptune and Uranus continue to fascinate astronomers as new techniques and observations reveal more and more about them. Now we have reports of temperature values for both planets and a new determination of Neptune's rotation period.

The outermost large planets, whose existence has long been known, have proven reluctant to give up their secrets (see "Uranus and Neptune," ASTRONOMY, February 1977). Direct observation of their tiny but distinct disks allowed astronomers to measure their diameters long ago, and the satellites orbiting both planets enabled pioneering astronomers of the 19th century to determine their masses to a high degree of accuracy. These two quantities allow the calculation of their average densities, which, being low like those of Jupiter and Saturn, soon identified them as "gas giants." Early in the 20th century, spectroscopy revealed the presence of methane and molecular hydrogen in the upper atmospheres of these distant members of the solar system, but little else is known concerning their structure and composition. The discovery of the rings of Uranus only two years ago dramatizes how far we still have to go in achieving a thorough understanding of these planets.

A particular difficulty has been the rotation periods of Uranus and Neptune. Quoted values have differed by factors of three or four, and even the most recent determinations still showed variations of a number of hours. The main difficulty stems from the lack of identifiable features with sufficient stability to allow a rotation period to be measured.

Now a new approach recently tried by David Slavsky and Harlan J. Smith of the University of Texas has yielded accurate periods of rotation for Neptune. Reporting in the **Astrophysical Journal**, Slavsky and Smith noted that Uranus has been found to have visible markings when observed through an interference filter centered on one of the strong methane bands which characterize the spectrum of the planet. A previous effort to measure a rotation period for Uranus demonstrated that very careful observations would be necessary because the features are very weak. Having established a sophisticated

PLANETS *continued on page 58*

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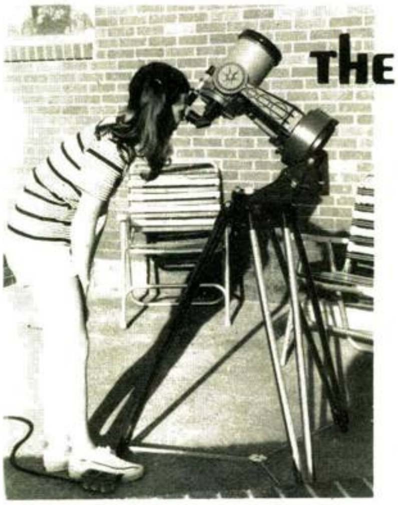

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VISA

PLANETS

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technique for their measurements, the two astronomers observed both planets over a long period of time. Their results for Uranus were ambiguous and hard to interpret, but in the case of Neptune, they reported that the observations seemed to establish a clear-cut, definite period.

Quasi-stable features on Neptune were identified and followed through a number of rotations. On the basis of the principal feature observed, the researchers found a rotation period of 18.44 hours with an error of about half a minute. This is slightly longer than the best previous estimates.

Also reporting in the **Astrophysical Journal**, M.T. Stier, W.A. Traub, and G.G. Fazio of the Harvard-Smithsonian Center for Astrophysics, E.L. Wright of the Massachusetts Institute of Technology, and F.J. Low of the Lunar and Planetary Observatory at the University of Arizona announced the results of far-infrared observations of Uranus and Neptune made by a balloon-borne telescope. An effective temperature for Uranus was determined of 58.5 ± 2 Kelvin, while that found for Neptune, much more distant from the Sun than Uranus, was nearly the same: 59.7 ± 4 K.

It has long been known that both Jupiter and Saturn radiate substantially more heat than they receive from the Sun, and that therefore they have internal heat sources. Previous measurements of the effective temperatures of Uranus and Neptune had indicated that Uranus has little or no internal heat source, while Neptune seems to radiate at least twice as much power as it receives from the Sun. The far-infrared measurements made by the team of researchers confirmed this finding.

Astronomers are eagerly awaiting the results of observations to be made in a few years with the orbiting Space Telescope, and are hopeful that the Mariner spacecraft due to rendezvous with Saturn later this year will remain functional long enough for its encounter with Uranus in 1986 and perhaps even Neptune several years later. Many of the mysteries still surrounding Uranus and Neptune will be solved when such observations become available.

BRIEFS

- The five European and American scientists selected last July to operate the experiments of the first Spacelab mission have begun their training in the United States. The selection and training of these non-NASA scientists to fly in space represents a departure from earlier NASA practices.

  Three of the Payload Specialists, as they are called, are from Europe. The first Spacelab mission, like the building of Spacelab itself, is a joint venture of NASA and the European Space Agency (ESA). Of the five men training for the mission, two — a European and an American — will actually go into space aboard Spacelab 1. The other three will operate the ground-based experiment equipment and will support the two in orbit.

- NASA has named the first four Space Shuttle orbiters to operate in space after famous sea vessels used in world exploration. Orbiter 102, scheduled to be launched into Earth orbit late this year, will be named Columbia. Subsequent orbiters will be named Challenger (099), Discovery (103), and Atlantis (104). The first orbiter constructed (Orbiter 101) was named Enterprise in 1976 after the flagship in the popular television series "Star Trek." But Enterprise was also the name of a sailing ship which took part in an important Arctic expedition between 1851 and 1854.

- A NASA review board has ascribed the failure of the Seasat satellite — which ceased to function last October 9 after 105 days of successful operation — to a "massive and progressive" electrical short circuit. The board criticized project engineers for failing to foresee such a possibility when designing and testing the satellite.

  Seasat was designed to demonstrate the effectiveness of remote-sensing techniques for satellite monitoring of ocean currents and conditions. Despite its short lifetime, this goal was successfully accomplished.

- A satellite designed to obtain data on the aerosols and ozone in the stratosphere was launched by NASA in late January. Dubbed SAGE (Stratospheric Aerosol and Gas Experiment), the satellite will analyze the effects of man's technological and industrial activities which may cause dangers to life on Earth's surface.

  The stratosphere is a very fragile and important part of Earth's environment; its ozone, for example, is known to protect the surface and its inhabitants from too much of the Sun's ultraviolet radiation.

- The explosion of a pump in a test version of the Space Shuttle late last December may force a delay in the first orbital flight, according to NASA officials. The shuttle's maiden flight has been scheduled for September 28, but that date assumed no unforeseen problems or unsuccessful tests.

  The explosion heavily damaged the test engine, and agency officials said it would take nearly a month to repair damage to the ground test stand.

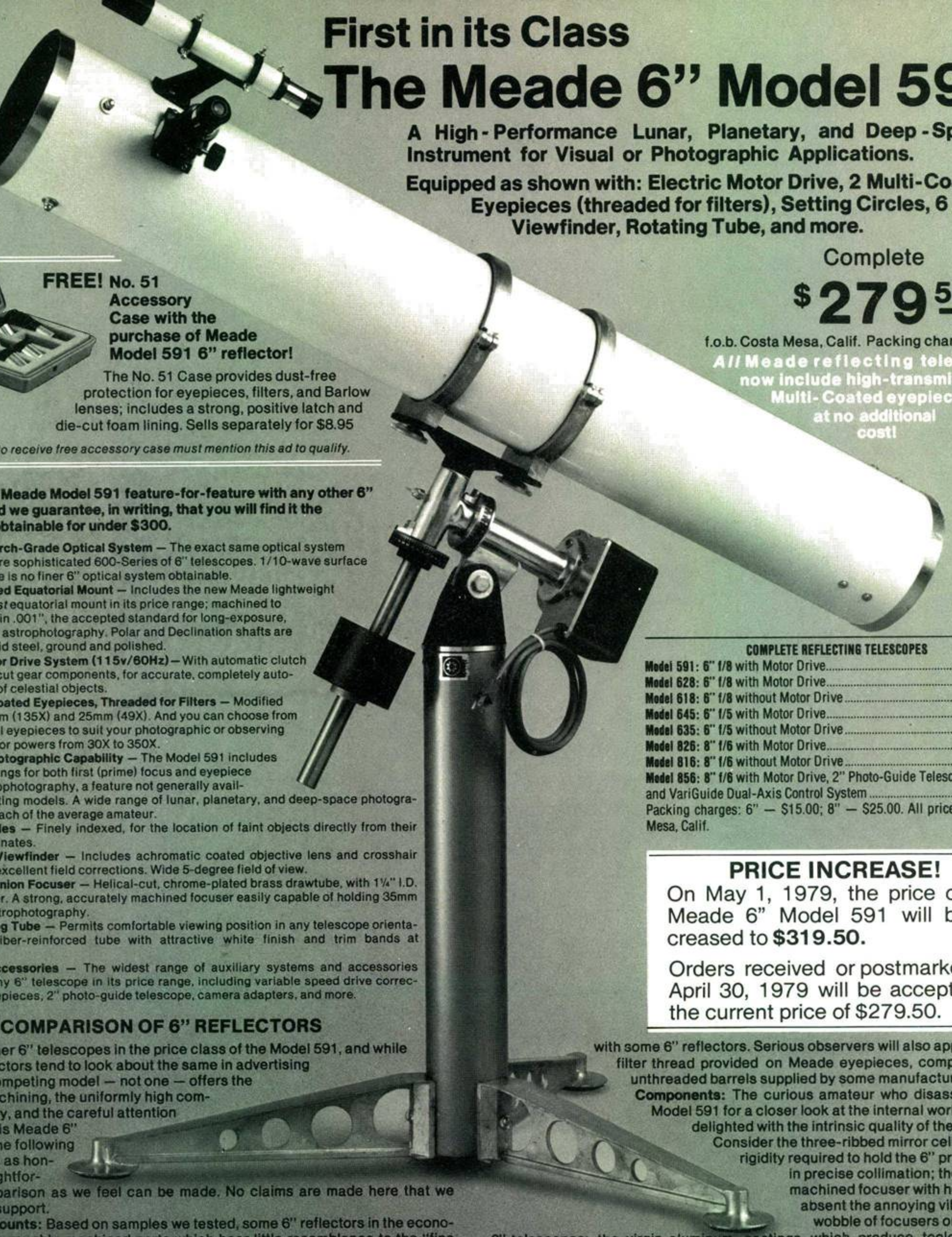
- A scientist at the Institut fur Astronomie of the University of Graz, Austria, has reported that observations of periodic light variations of two asteroids, 387 Aquitania and 776 Berbericia, suggest that the two have rotation periods close to 24 hours and are, therefore, difficult to establish. Dr. H.J. Schober said the period of Aquitania could be either 24 hours, 12 hours, 16 hours, or even 48 hours. Berbericia's period could be either 23 hours or perhaps 15.3 hours.

- On May 9, 1979, the Smithsonian Institution and the University of Arizona will officially begin operations of the Multiple Mirror Telescope at the Mt. Hopkins Observatory in Arizona. The Multiple Mirror Telescope (MMT) represents the first major departure from conventional telescope construction in more than a century. Instead of using a single large mirror, the MMT employs six separate mirrors, with the light gathered by each brought to a common focus and maintained as a single image by a unique active optics system incorporating a computer. In addition to serving as the prototype for even larger telescopes of the future, the MMT will also be a powerful tool for today's astronomical research.

- If you're a scientist with an interest in the planet Venus, NASA might need you. The agency is asking interested scientists to propose experiments for a 1984 planetary mission designed to provide a more detailed global view of the surface of Venus. The mission will be accomplished by the Venus Orbiting Imaging Radar (VOIR) to be launched by the Space Shuttle. VOIR will circle the planet for at least seven months, taking radar pictures and making measurements of the atmosphere and the surface of Venus in the most extensive scientific examination ever made of the cloud-covered planet.

- The ardor of persons interested in the space program — space cadets — has led many to collect just about every book and model concerning space. Few, though, can match the devotion of Ake Facrell, 33, a Swedish computer programmer. In June 1978, Facrell flew 6,000 miles from Stockholm to Los Angeles, drove to Palmdale, and spent two hours watching Space Shuttle Orbiter 102 being assembled. Then he flew home.

  "*I touched it!*" said Facrell. "It was the best day of my life."



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A FRANK COMPARISON OF 6" REFLECTORS

There are other 6" telescopes in the price class of the Model 591, and while most 6" reflectors tend to look about the same in advertising photos, no competing model — not one — offers the precision machining, the uniformly high component quality, and the careful attention to detail of this Meade 6" telescope. The following discussion is as honest and straightforward a comparison as we feel can be made. No claims are made here that we cannot fully support.

Equatorial Mounts: Based on samples we tested, some 6" reflectors in the economy class use roughly machined parts which bear little resemblance to the "fine instrument" descriptions advertised. "Hand-punched" castings, wobbly shafts, and inferior machining are never a part of the Meade Model 591. Meade equatorial mounts are fully machined on $10,000 lathes to tolerances within .001", and are capable of the fine guiding absolutely essential for serious observing and quality astrophotography.

Eyepieces: The Modified Achromatic eyepieces supplied with the Model 591 yield apparent fields of view significantly wider than the Ramsden eyepieces supplied with some 6" reflectors. Serious observers will also appreciate the filter thread provided on Meade eyepieces, compared to the unthreaded barrels supplied by some manufacturers.

Components: The curious amateur who disassembles his Model 591 for a closer look at the internal workings will be delighted with the intrinsic quality of the instrument. Consider the three-ribbed mirror cell, with all the rigidity required to hold the 6" primary mirror in precise collimation; the beautifully machined focuser with helical gears, absent the annoying vibrations and wobble of focusers on competing 6" telescopes; the virgin aluminum castings, which produce tooled surfaces almost as smooth as glass.

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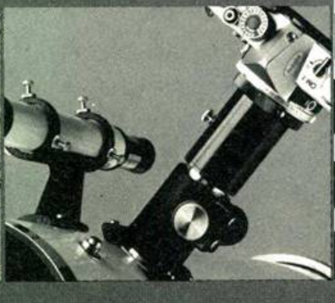

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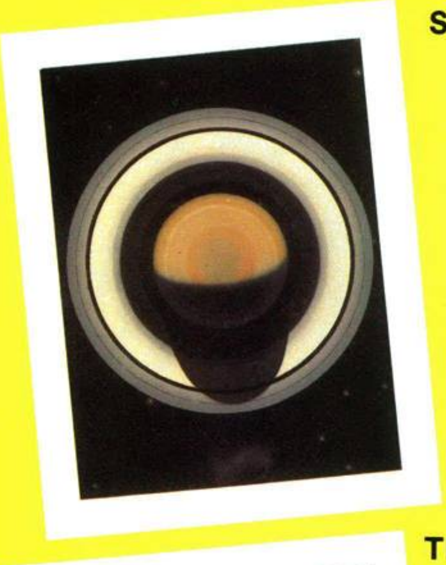

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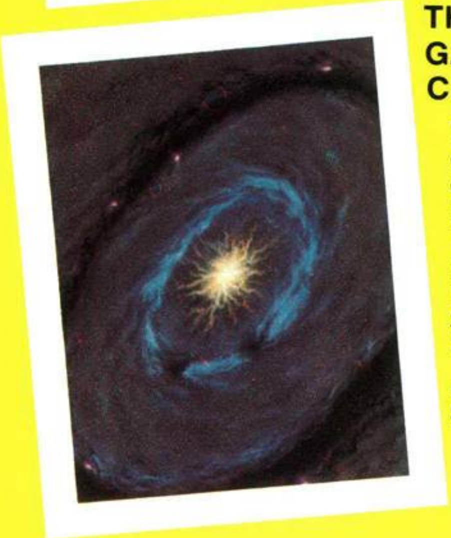

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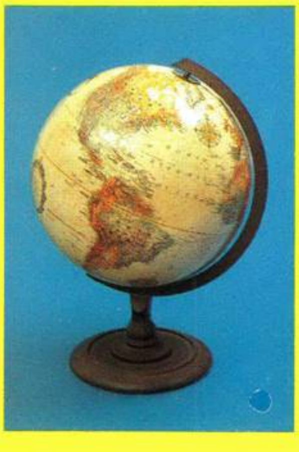

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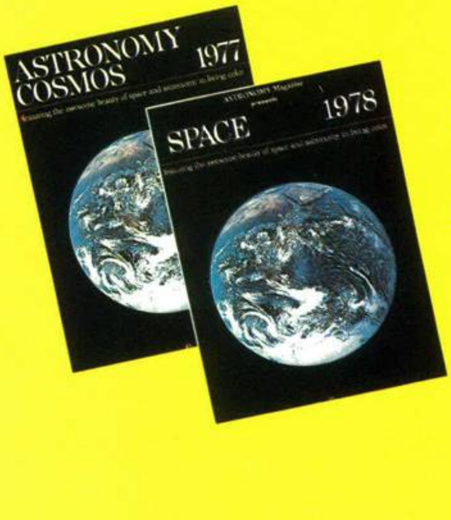

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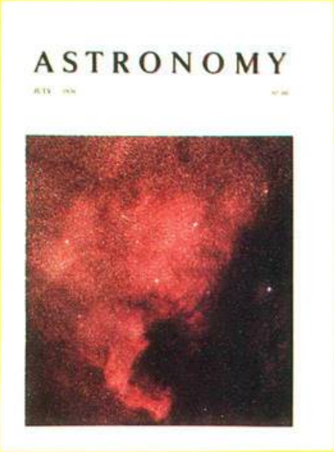

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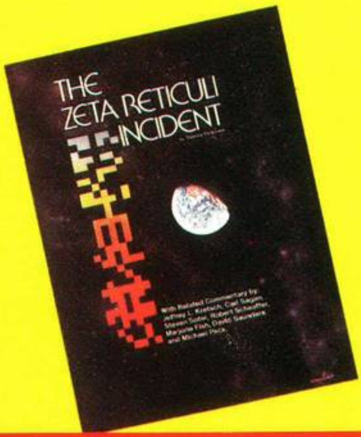

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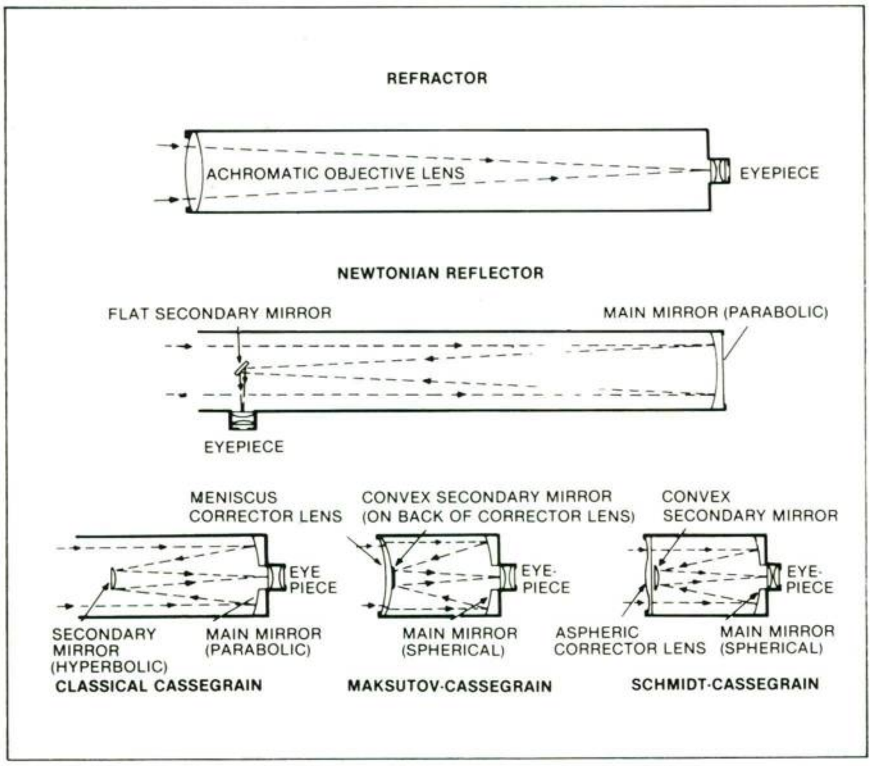
REFRACTOR, NEWTONIAN, OR CASSEGRAIN ???


REFRACTOR
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EYEPIECE
NEWTONIAN REFLECTOR
FLAT SECONDARY MIRROR
MAIN MIRROR (PARABOLIC)
EYEPIECE
MENISCUS CORRECTOR LENS
CONVEX SECONDARY MIRROR (ON BACK OF CORRECTOR LENS)
CONVEX SECONDARY MIRROR
EYE PIECE
EYE-PIECE
EYE-PIECE
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MAIN MIRROR (PARABOLIC)
MAIN MIRROR (SPHERICAL)
ASPHERIC CORRECTOR LENS
MAIN MIRROR (SPHERICAL)
CLASSICAL CASSEGRAIN
MAKSUTOV-CASSEGRAIN
SCHMIDT-CASSEGRAIN

***Main types of telescope optics** are diagrammed at the left. All are shown drawn to scale. Objectives are eight inches in diameter, and have focal ratios of 1:10 or f/10. Thus the focal length of each scope is equal to 80 inches. The task of any objective, be it lens or mirror, is to bring light to a focus and form an image. This image is small, so an eyepiece— really just a simple magnifier—is used to enlarge it for easy viewing. Refractors bend light as it passes through the objective lens. Reflectors reflect light from a curved mirror. The mirrors are concave, and usually ground to a parabolic curve. They are made of thick glass—usually Pyrex—and are coated with a fine aluminum film. Some are given a special treatment to preserve the mirror finish. The classical Cassegrain reflector is shorter and easier to handle. The two ultracompact designs are catadioptrics using both lenses and mirrors.*

When confronted with the choice of which type of telescope to choose, there is an abundance of information to sort through from the various manufacturers. All try to claim theirs is the best and state all other designs are not good. The truth is that all designs have some excellent merits, as well as, some negative ones.

All designs can perform satisfactorily if properly and responsibly made. As our company has stated in the past, the most important aspect of a telescope is the aperture. In addition, several other factors must be considered such as portability, cost, versatility, useability, maintenance, etc. to suit the individual needs.

Let's look at the various popular designs available and point out some good things along with the bad:

THE REFRACTOR

The refractor is mechanically simple, rugged, and essentially maintenance free. It's closed tube design protects its optics and eliminates image-degrading air currents inside the tube.

Small refractors (2.4" to 3.1") are seen the most in department stores and imported from Japan. In the past these instruments have been reasonably priced ($100.00 to $300.00). During the last few years the prices have jumped substantially. Advertising claims of these stores are misleading, claiming those instruments to be 600X, etc. which is just empty magnification. The maximum power is 60X the diameter of the lens. For example a 3" telescope has a maximum power of 180X (3x 60).

If you investigate refractors in apertures large enough (5" or larger), for serious observing or photography, you'll soon discover this design has a major drawback — cost!! A quality 5 inch refractor bears a price tag approaching $10,000.00. In terms of value for aperture, this instrument compares poorly to the alternative Newtonians and catadioptrics currently available.

The refractor does suffer from chromatic aberration (color fringes). This, for example, is important in studying the colors of the stars and the planets. It also suffers from severe coma at the edges of the field.

An advantage of the refractor is that aperture for aperture (some focal lengths) it offers somewhat less light loss. In very small sizes, its absence of a secondary-mirror obstruction (or diagonal obstruction) generally gives it a slight edge in performance over Newtonians and catadioptric telescopes. They usually come in long focal lengths (f/15 or slower) which provide excellent views of lunar and planetary subjects and also double stars.

You can use most refractors for terrestrial use but the near focus usually prohibits detailed studies of subjects less than 100 feet. Also the focal lengths are usually long (f/15 of slower) which make photography more difficult.

Refractors are extremely bulky and not very portable after the instrument reaches a aperture of 3 inches or so. A quality 5 inch typically weighs several hundred pounds. Any bump of the tube during an observing session requires a considerable amount of time to quiet down. Most manufacturers do not even list the weights so you won't be discouraged immediately.

Continued on next page

THE NEWTONIAN REFLECTOR

If one attends a star party you will see many Newtonian telescopes; either homemade by amateur astronomers or commercially purchased units. For beginners the Newtonians are relatively inexpensive.

Much of the potential performance of the Newtonian is often sacrificed to air turbulence within their open-ended tubes which can put it out of commission for the night. This open tube design exposes two delicate mirror surfaces to airborne contaminants which means the mirrors must be recoated periodically. In a Newtonian the diagonal obstructs some light and its necessarily small size somewhat limits the working field.

The Newtonian presents an excellent value for the economy seeker of large aperture compared to a refractor. An amateur can purchase a 12½ inch for the modest price of approximately $2000.00. Small 6 inch instruments can be purchased for as little as $250.00 to $400.00.

Most Newtonian optical systems are well made. The only optical aberration it suffers from is coma; a comet-like distortion of images that increases the closer the images are to the edge of the field.

You can use a Newtonian for terrestrial applications but it is awkward and the near focus is seldom under a few hundred feet.

An advantage of the Newtonian over the refractor of the same aperture and f/number, is that it has a slightly shorter tube. Although this is not really significant since even a 6 inch Newtonian can weigh up to 100 pounds. The long tube of a Newtonian requires a large and massive mount to achieve a reasonable degree of stability. If one needs to take the instrument out to a remote site it can be quite an experience and time consuming along with the necessity of a large vehicle (trailer or pick-up truck) to transport it due to the bulkiness and weight.

When using a large aperture Newtonian a ladder is required to reach the observing position. We have seen amateurs poised on unstable ladders posing a serious safety problem.

Compared to refractors and catadioptrics, the Newtonian is relatively fragile and requires complicated optical realignment after minor bumps and jars.

An advantage many Newtonians have over refractors and catadioptrics is that they are available in short focal lengths (f/5 to f/8) which give excellent bright images for deep-sky objects (although it hinders lunar and planetary work).

THE CASSEGRAIN

The classical Cassegrain reflector telescopes are an improvement over the Newtonian. It uses a short focal length parabolic mirror in conjunction with a small hyperbolic secondary mirror. The combination gives the same performance as the long tube Newtonian but in a more compact size requiring a far less massive mount for the same degree of stability. It also places the eyepiece at a more convenient position. The disadvantages of the Cassegrain reflector telescope are the difficulty in parabolizing the short focal length primary mirror to the required degree of accuracy (much more costly than a Newtonian) and the open tube construction which also exposes the mirrors to contamination. It also suffers coma to the same degree or more as the equivalent Newtonian.

CATADIOPTRICS

The catadioptric instruments combine the best ingredients of the above to form the most advantageous telescope for many. These instruments are relatively new and have been commercially available for only about 20 years. They are now the most popular type of instrument marketed throughout the world in 3½" and larger apertures.

Catadioptrics have closed tubes which eliminates image degrading tube currents and makes the optics basically maintenance free. Due to the folding of the optical paths the instruments are extremely portable. A Celestron 8" Schmidt weighs in at only 21#.

Like the Newtonian it is totally free of chromatic aberration (with the Schmidt-Cassegrain, at least, and nearly so with the Maksutov). Moreover, the additional optical elements permit correction of various off-axis (or edge-of-field) aberrations (coma) especially with the Schmidt-Cassegrain and somewhat with the Maksutov.

Catadioptrics are easy to set up and use. Large apertures still come in relatively small packages.

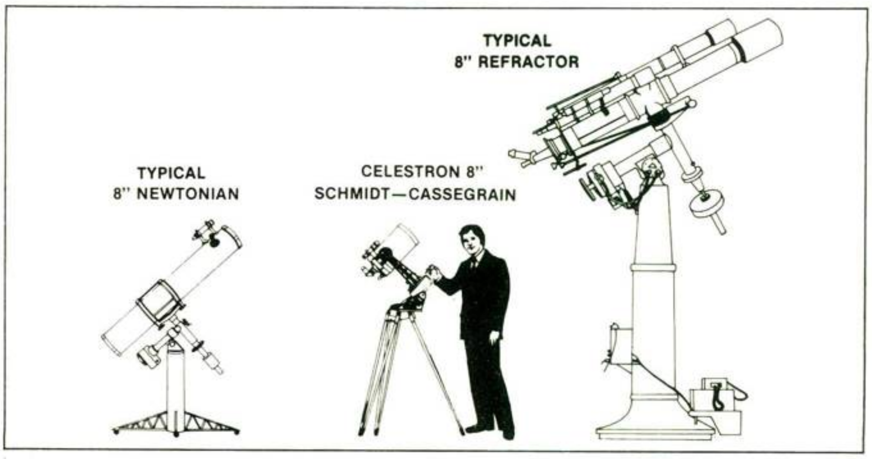
Are there any disadvantages to catadioptrics? One of the few is cost. They do cost more than Newtonian reflectors of equal aperture but still considerably less than refractors. We sometimes say that if one wants to mainly observe, lives in a good dark-sky location, and wants the largest aperture he can afford then the Newtonian is the best selection because it is less expensive. But also take into consideration the larger dome needed, safety factors, maintenance, etc.

Another disadvantage of most catadioptrics is that they are longer focal lengths (f/10 to f/20). The long (f/15 and longer) are good for lunar and planetary work. The f/10 systems are a good optimum ratio for lunar, planetary, and also deep-sky work. The Newtonian's of fast speeds (f/5 or so) make brighter the deep-sky objects than do the catadioptrics (although Celestron does have adaptors to make their Schmidt-Cassegrain usable at f/5).

Many catadioptric instruments are ideal for terrestrial observing and/or photography with near focus with some instruments of 10 feet or less. Speeds of f/10 or faster provide the best instruments for this application. Using a telescope for terrestrial work expands the useability of your telescope and adds greater enjoyment.

Collimation (alignment) is seldom a problem whether one is using an adjustable instrument (as a Schmidt-Cassegrain) or a permanently aligned Maksutov.

Of the catadioptrics available we feel that the Celestron offers the most value for your money and provides the most extensive array of visual and photographic accessories available to cover the interests of the varied consumer audience.



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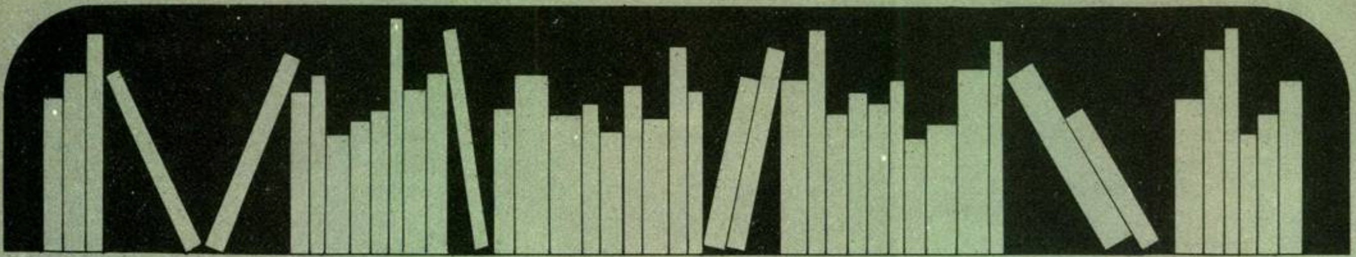


ASTRONOMY REVIEWS

The Road To The Stars

by IAIN NICOLSON

224 page (illus.), hardcover, $14.95
William Morrow (1978)

Iain Nicolson is a British writer best known for his excellent popular reference books on astronomy and space science; however, some readers may find his latest work reads too much like a reference book to be an easy night's reading. But it's very much worthwhile if they persist, since the text consists of assorted short subjects relating to the human colonization of the Galaxy.

Beginning with a proper view of man's place in the universe, Nicolson traces human development from its very origins to our present period of unmanned planetary exploration. The reader is gently introduced to Newton's Third Law of Motion and shown the fundamentals of celestial mechanics, rocket propulsion, as well as the more complex issues of interstellar hazards. Each topic is presented in nontechnical terms and is accompanied by helpful illustrations.

The chapters are divided into three main sections. The first reviews possible reasons for undertaking such a voyage. The author suggests that humanity's swelling numbers and the need for new resources will force us out into space. This is certainly a debatable point! While it's true the vast resources of our solar system lie waiting to be tapped, it does *not* mean this process of exploitation will continue past Pluto. Sending an expedition to Alpha Centauri could hardly serve the people of Earth. Without some sort of faster-than-light drive, trade between two star systems will always be confined to information or ideas, and perhaps small artifacts. Therefore, there's only one valid reason for traveling to the stars at the present time: to satisfy our need to explore.

The second section deals primarily with current and predictable technology which will serve as means for the human race's expansion into the galaxy. Readers of the **Journal of the British Interplanetary Society (JBIS)** will find most of the material familiar. It covers topics such as the Project Daedalus Starship Study, the fusion ramjet and the laser photon sail, all of which have been examined recently in that publication. Nicolson recounts these possibilities faithfully, adding little new information. Later on, he ventures to the limits of our present knowledge by looking into a feasible means of traveling faster-than-light. Although the author doesn't dismiss the concept entirely, he quite properly finds the idea very unlikely.

The third section of the book is concerned with human reactions to starflight. It focuses on the psychological impact to the crew and the Earth-bound society they leave behind. There are also brief forays into the areas of interstellar evolution and the possibility of contact with another intelligence.

Additionally, there is an epilogue to the book in which the author attempts to predict the time scales for these developments over the next ten thousand years (or so)!

There are 24 pages of stock NASA black and white photos and eight original color paintings (nine if you count the cover) by free-lance space artist Andrew Farmer. These are placed here and there in the book apparently at random.

This volume is an adequate overall summary of our present knowledge about interstellar travel. The information it contains will not become obsolete or outdated quickly, and it also has a fairly complete index. For these reasons, **The Road to the Stars** might make an excellent book for the novice space buff. *Thomas R. Schroeder.*

◆

Earthwatch

by JULIUS SCHWARTZ

63 pages (illus.), hardcover, $7.95
McGraw-Hill Book Company (1977)

Earthwatch might appear at first to be a study or "enjoyment" of our world by those astronauts who have viewed the world from outside the atmosphere. However, opening this book by Julian Schwartz (with illustrations by Radu Vero) shows you that every person can experience the Earthwatch observations heretofore restricted to orbiting spacemen. You don't have to be fired into space on a gigantic skyrocket and later returned in a ball of fire — a great relief to timid sky watchers. Instead, the book jacket explains, space-time investigations can be made with an Earth globe, and on the surface of Earth itself.

It's surprising that the simple principle of using an Earth globe placed in the sunlight to demonstrate sunrise and sunset, time and Earth as a clock, rotational speeds at different latitudes and many other Earth facts, hasn't been published before. Perhaps it's the simplicity of the idea that's made others believe there was no need to put it in print. Anyway, teachers and educators can be thankful to Mr. Schwartz for the very lucid and interesting way the book has been prepared and illustrated.

Back in the early 1900s, there were many books for the beginner in which "practical" astronomy on an observational level was presented. Readers were encouraged to make simple pieces of equipment to follow the changing altitude of the Sun at noon, or to determine the equation of time and the difference between the mean and actual Sun. These firsthand acquaintances in observing inspired many young enthusiasts to become professional astronomers. The application of pocket calculators and other modern tools are no substitute for making experiments to learn how the seasons take place and other facts about the world we live on.

I would recommend this book for juvenile study groups in astronomy, while grade school teachers teaching about Earth will find it most useful in explaining how we are oriented in space and time. (The concepts of **Earthwatch** were introduced to some of the classes at the McDonnell Planetarium in St. Louis in the fall of 1978.) By using a small flashlight bulb as a light source and a plastic lens about 10 inches in diameter, it's possible to make parallel light rays and simulate sunlight with a nine inch Earth globe.

I found one questionable statement on page 45: that for someone at the poles around the time of the equinoxes, half a Sun would be making a complete passage around the horizon. At the equinoxes, refraction would raise the Sun above the horizon, making it necessary for the Sun to be more than its own diameter below the horizon if it's to appear as a half disk. The phenomenon described on page 45 would be true only if Earth lost its atmosphere!

The somewhat forgotten art of simple but exciting experiments in astronomy lives again in books like this, giving young people in the last part of the 20th century the opportunity to regain something overlooked in the past few decades. If Mr. Schwartz doesn't publish other books like this, perhaps new authors will be inspired to prepare and publish more practical observational astronomy books. *Robert E. Cox.*

◆

NEW ASTRO-BOOKS

Observer's Handbook 1979
edited by JOHN R. PERCY
140 pages, paperback, $4.00 (Can.)
Royal Astronomical Society of Canada (1978)

This annual publication has become an indispensible aid for the observer, and many will be glad that its size has been increased to 140 pages (up from 128 in last year's issue). Order from the Society at 124 Merton St., Toronto, Ontario, Canada M4S 2Z2.

To The Red Planet
by ERIC BURGESS
181 pages (illus.), hardcover, $19.95
Columbia University Press (1978)

The story of the Viking project is told by a well-known science writer. Fully illustrated with behind-the-scenes photos as well as Mars images, the book surveys the scientific results of the mission. By using an anecdotal approach, the author has also succeeded in bringing out some of the personalities involved in the project.

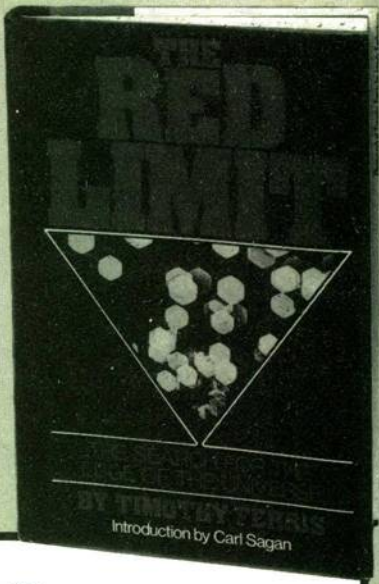
Neutron Stars
by J. M. IRVINE
157 pages, hardcover, $19.95
Oxford University Press (1978)

This is a survey of the physical properties of neutron stars; the presentation is aimed at the graduate student level.

Spaceships of the Mind
by NIGEL CALDER
144 pages, (illus.), hardcover, $14.95
Viking Press (1978)

In 1978, the BBC produced a television series about possible techniques for space colonization. This fully illustrated book is the print version of the series, and makes an excellent introduction to the subject for the general reader.

THE RED LIMIT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Introduction by Carl Sagan

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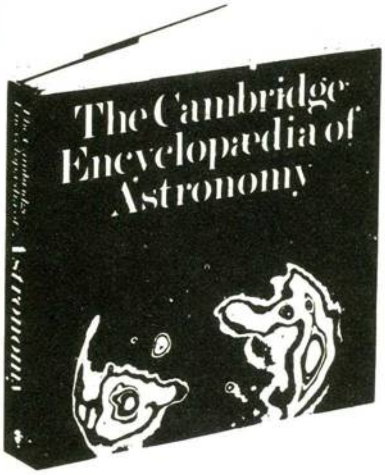

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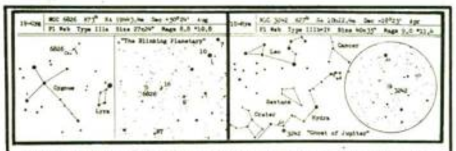

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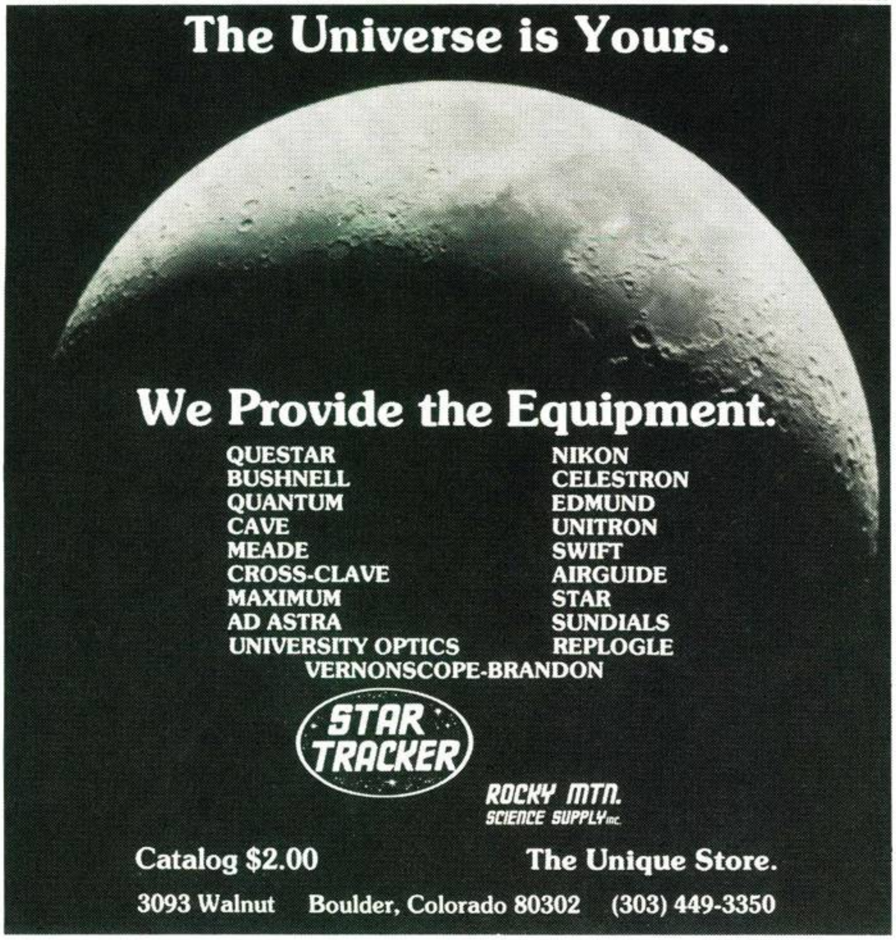

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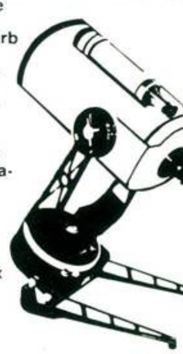

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WANTED — "The Binary Stars" by Robert G. Aitken; "The Galactic Novae" by C. Payne-Gaposchkin; "The Internal Constitution of the Stars" by Arthur Eddington. Will pay $10.00 for all three plus airmail postage. Write Philip Stahl, "Sunnyside", Chelsea Gardens, St. Michael, BARBADOS.

WANTED — 1973 and 1974 issues of ASTRONOMY. Contact F. Michael Witkoski, P.O. Box 624, Camp Hill, PA 17011. Phone (717) 938-4878.

INFORMATION WANTED — Correspondence with persons (14-20) interested in astronomy, science fiction, science fact and fantasy. Write David deGil, 31 John St., Fairfield, NJ 07006.

INFORMATION WANTED — Information or where to get it on building full size working model of Stonehenge. Send to Michael McNicholas, Box A, Malibu, CA 90265.

INFORMATION WANTED — Correspondence with persons interested in meteorites or those who have collections of same. Also any information on the subject. Write Raymond Wittstock, 22001 Eastwood, Oak Park, MI 48237.

ANNOUNCEMENT — The Astronomical Society of the Pacific is compiling regional astronomy directories, listing amateur clubs, observatories, planetariums, courses, and stores for the US and Canada. For a free listing questionnaire, send a stamped, self-addressed envelope to Directories, A.S.P., 1290 24th Ave., San Francisco, CA 94122.

ANNOUNCEMENT — Virginia Association of Astronomical Societies 5th annual meeting, May 18-19, NASA Langley Research Center, Hampton, Va. Astrophotography contest, telescope making competition, slide presentations and interesting paper sessions. Contact VAAS, c/o Joseph R. Guth, 1036 Mineola Dr., Apt. 101, Virginia Beach, VA 23462.

ANNOUNCEMENT — General Assembly '79; Royal Astronomical Society of Canada, at London, Ontario; May 18-21. Displays, papers, prizes, trips, observing. Special guest: Dr. Gerard K. O'Neill. Details: London RASC, P.O. Box 842, Station "B", London, Ontario, CANADA N6A 4Z3.

ANNOUNCEMENT — Amateurs in northern New Jersey are invited to join the Sheep Hill Astronomical Association, which recently completed construction of an observatory equipped with a 16" telescope. Write P.O. Box 122, Boonton, NJ 07005 or call Rick Kurczewski (201) 595-7843.

ANNOUNCEMENT — Comet News Service provides you rapid notification of bright comet discoveries, observing information, and reviews of the very latest developments in cometary astronomy. FREE for long, self-addressed, stamped envelopes. Mail to CNS, 750 Legion, New Haven, CT 06511.

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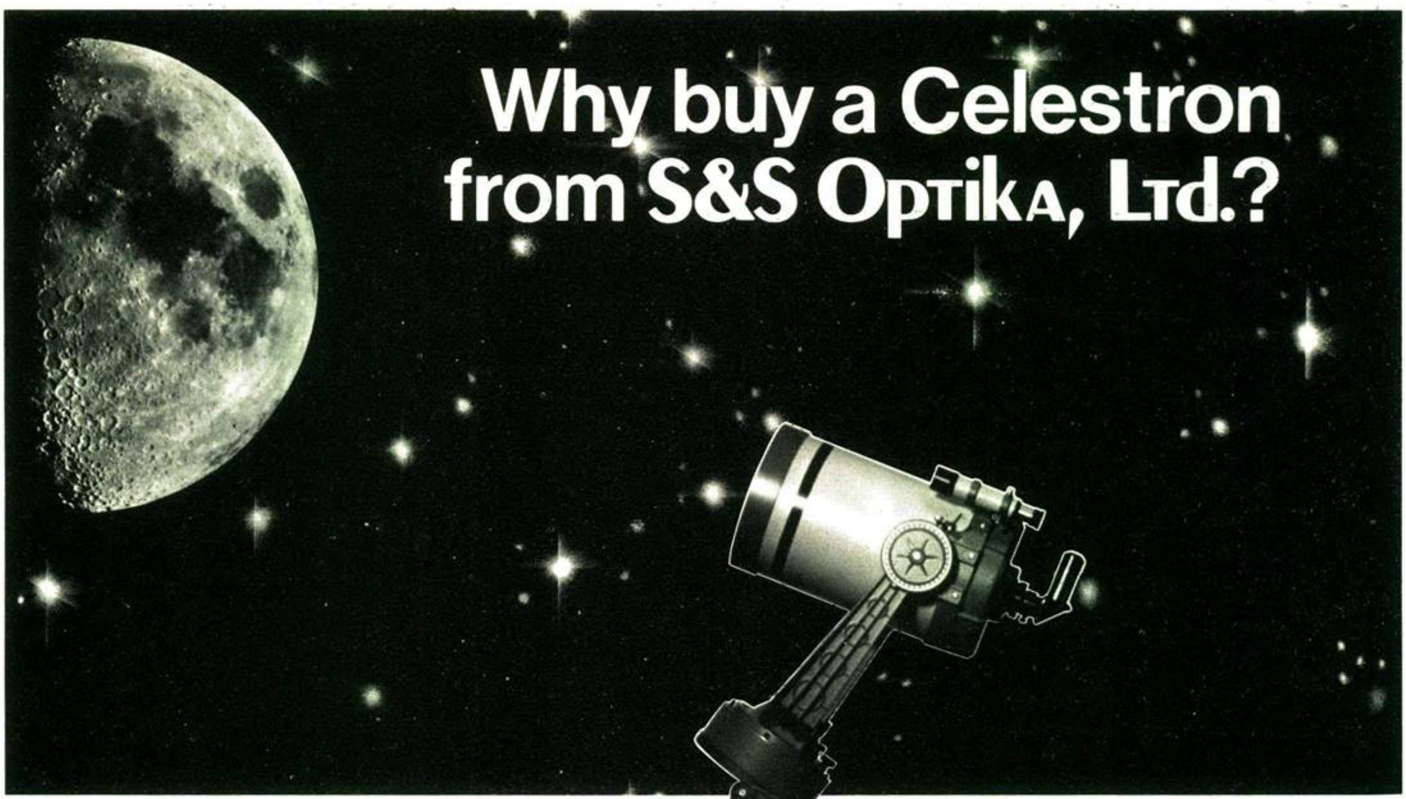

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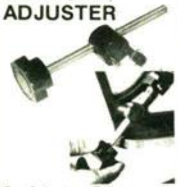

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STAR DOME

APRIL

by
Dewey Schwartzenburg
and
James Mullaney

"The Lights in the Sky are Stars" is the title of a poem written by Kenneth Rexroth for his young daughter Mary. He writes of the beauty of the night sky and the wonder of astronomical events such as comets and solar and lunar eclipses. The title of the poem is strange — surely, we think, *everyone* knows that the lights in the sky are stars. But *do* we?

For all too many people these days, the lights in the sky are just that — lights. They may know they're called stars, but they don't really look at them. They don't know their patterns and they can't call them by name. The stars are just lights, nothing more.

Most people, of course, can find the Big Dipper (provided they know enough to look for it in the north!) and perhaps a few will recognize Orion, but that's about it. Not one in a thousand would be able to *name* the stars of the Big Dipper, or, for that matter, could name any star at all.

In the past, skylore was an important part of every society and culture, but today, ironically just when we have begun to know the truths of the stars, we live in a society which knows them only as lights in the sky. True, we do have our own modern celestial myths and tales, stories and legends, but they are pallid and weak compared to those of our ancestors. A recent survey in England found that more young people in that country believed that UFOs were visitors from other worlds than believed in God — but we can be sure that very few of them would be able to identify even a single star from which their supposed travelers might have come. And how many of those who are so eager to discuss the characteristics of each astrological sign could actually recognize Taurus, or Cancer or Scorpius (not Scorpio as they call it), or any of the others in the sky? (When I'm asked, "What's your Sign?", my reply is: "Yield!" — given with a big smile if the questioner is especially attractive.)

The skylore of modern society consists of an astrology and a UFOlogy totally divorced from those lights in the sky. So how do you start to learn the stars, to make them into familiar friends? Not all of us have fathers like the poet Kenneth Rexroth; most of us are very much on our own. The best way, of course, is to learn from a friend. A talented tennis player may be reluctant to play with a beginner, but I know of no true lover of the stars who isn't more than eager to introduce them to someone who wants to know them, but knows nothing of astronomy.

Many local astronomical societies offer courses in astronomy for beginners, and this is another excellent way to learn the deeper joys of stargazing. If you are fortunate enough to live in or near a city with a public planetarium, by all means visit it — often. Most change their shows every month, and while the artificial sky of the planetarium, dramatic and beautiful as it is, cannot be compared with the glory of the real thing, it can be used to teach in marvelous ways. Also, many planetariums offer courses in astronomy for beginners at a nominal charge or for free.

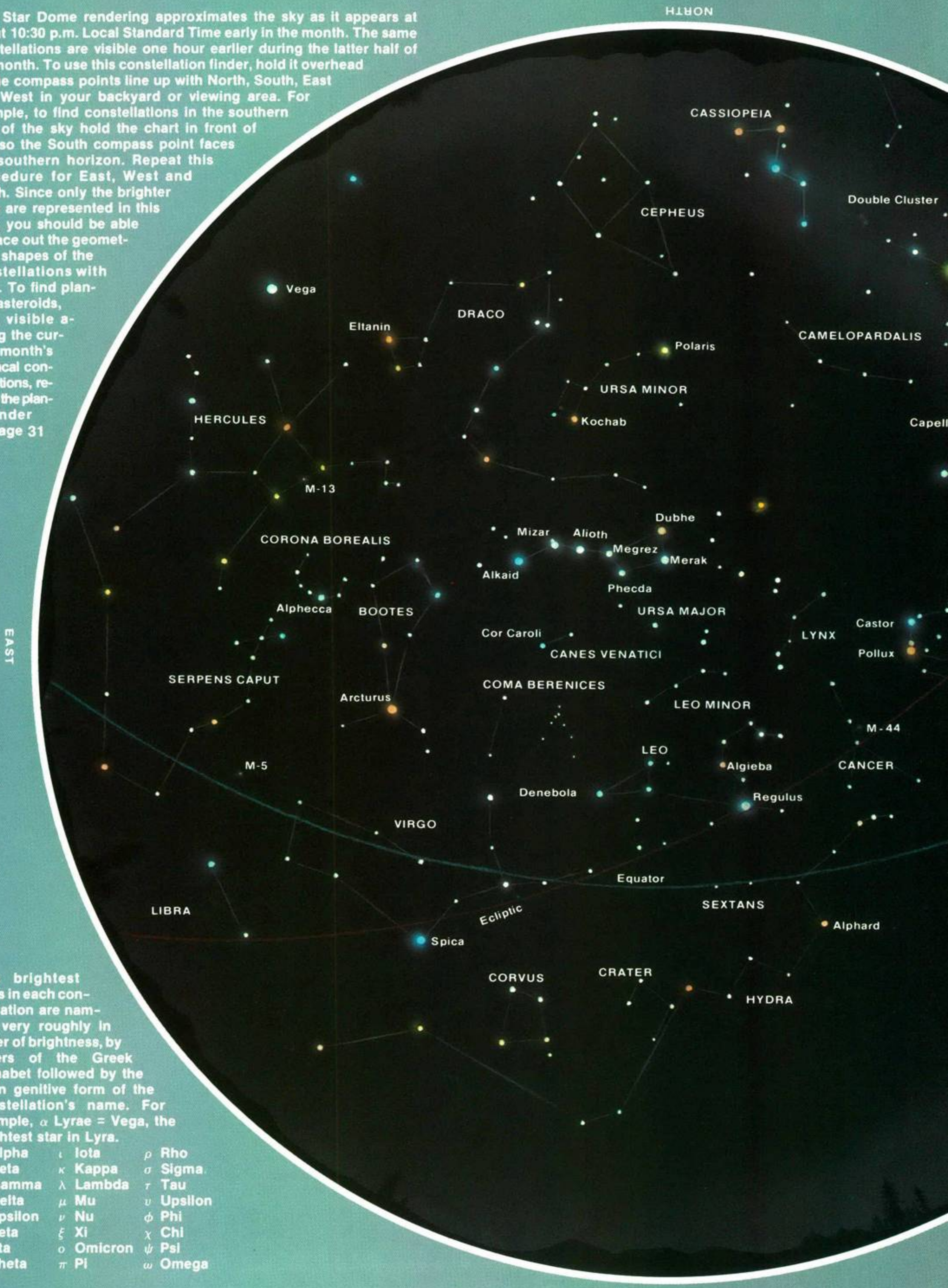
Unfortunately we rarely get such views of the night sky as we can in a planetarium — a planetarium sky, at least, is never plagued by clouds, light pollution, or poor seeing. And you're never cold, even when the stars of winter roll slowly across the sky above. For those of us who live in large cities, the planetarium will be the one place in town where the sky can be seen in all its glory. Even without other kinds of air pollution, the light pollution of a large modern city is enough to destroy the beauty of the night sky for miles around.

The modern planetarium is a direct descendant of the old orrery, a device for portraying the relative positions and motions of the Sun, Earth, Moon, and planets. An orrery in effect is a miniature model of the solar system, often mechanical, which recreates the motions of heavenly bodies in their orbits. Some fascinating and beautiful examples of past centuries survive today, such as the large orrery constructed in 1787 by Joseph Pope, now on display at Harvard University's Houghton Library.

But orreries cannot compare with the dramatic represention of the actual appearance of the night sky provided by a planetarium, from any position on Earth, at any time. The modern planetarium is a product of this century. Conceived in 1919 by Walther Bauersfeld, the first modern planetarium projector was built in 1923 by the Carl Zeiss optical works in Jena, Germany, and installed in the Deutsches Museum in Munich. By 1940 there were five planetariums in the United States, and today nearly every city of any size boasts at least one.

A planetarium is far more than just a museum, although many also provide exhibits. It is more an educational theater where scientific knowledge is conveyed in a dramatic, entertaining way, and it can be a particularly delightful way to recapture a feel for our place in the cosmos. "In addition to communicating positive knowledge," writes Helmut Werner of the modern

This Star Dome rendering approximates the sky as it appears at about 10:30 p.m. Local Standard Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder on page 31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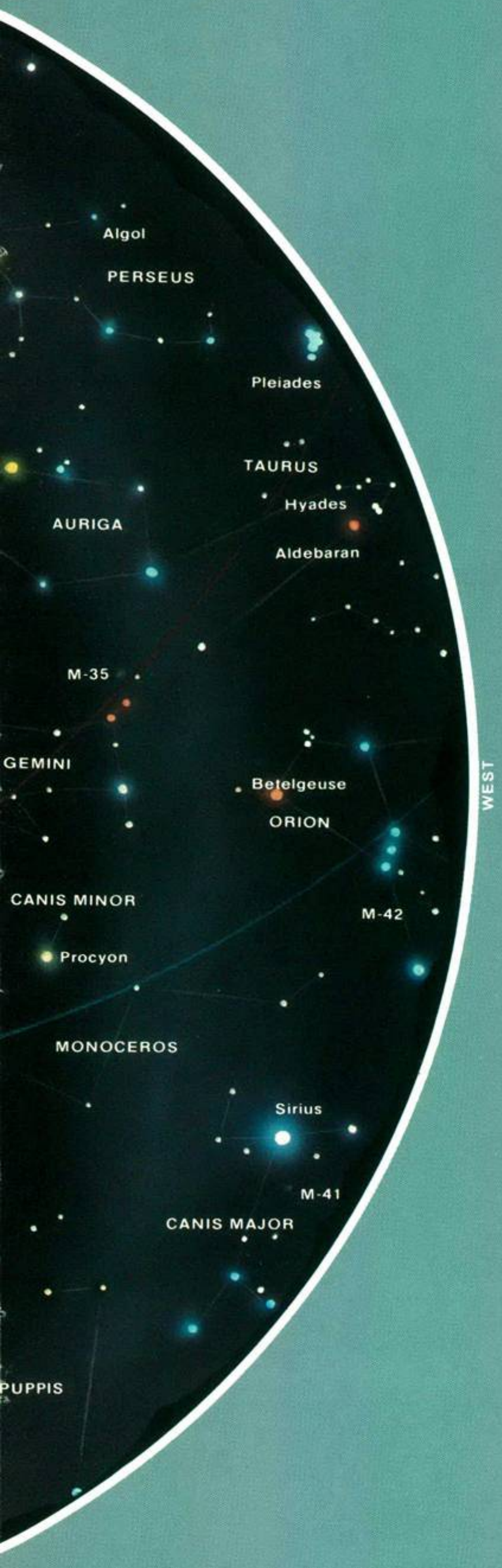
Algieba
CANCER
Denebola
Regulus
VIRGO
Equator
LIBRA
SEXTANS
Ecliptic
Alphard
Spica
CRATER
CORVUS
HYDRA
SOUTH

The brightest stars in each constellation are named, very roughly in order of brightness, by letters of the Greek alphabet followed by the Latin genitive form of the constellation's name. For example, α Lyrae = Vega, the brightest star in Lyra.

α Alpha
β Beta
γ Gamma
δ Delta
ϵ Epsilon
ζ Zeta
η Eta
θ Theta
ι Iota
κ Kappa
λ Lambda
μ Mu
ν Nu
ξ Xi
o Omicron
π Pi
ρ Rho
σ Sigma
τ Tau
υ Upsilon
ϕ Phi
χ Chi
ψ Psi
ω Omega

Map Centered on 40° North Latitude



Map by Adolf Schaller

planetarium, "it must leave the spectator with a deep ethical impression of the wonders of the heavens."

The lights in the sky *are* stars — wonderful, mysterious, and endlessly fascinating!

Close-Up

Ursa Major

Third largest of all sky precincts is Ursa Major, the Great Bear of the heavens. Within its spacious confines lies the well-known Big Dipper, "its sequence of seven bright stars... known to everyone," in Muirden's words. Webb pointed out long ago that "This familiar constellation offers a large field to the persevering observer. It must be borne in mind that it extends far beyond the region occupied by 'the seven stars'; and, from the unmarked character of some parts of it, several telescopic objects will require care in their identification."

Ursa Major is noted for its nest of remote galaxies, among the brighter of which are five from Messier's list and many of Sir William Herschel's discoveries bearing NGC numbers. Beyond these lurks a host of fainter ones, so densely packed in places that within the bowl of the Big Dipper alone, more than a million of them can be detected with the 200-inch telescope at Palomar. We begin by sampling the wonders lying nearby within our own galaxy, and then journey outward to examine firsthand a few of those vast island universes.

Mizar and Alcor

The striking naked-eye pair formed by Mizar and Alcor (Zeta [ζ] and 80 Ursae Majoris, respectively) at the "bend" of the Dipper's handle is a beautiful triple in even the smallest of telescopes. Ranking as one of the finest of all stellar objects, it thrills beginning and veteran observers alike — once its acquaintance is made, it seems like an old friend to whom we can turn time and again for inspiration. Second magnitude Mizar and fourth magnitude Alcor are spaced some 12 minutes of arc apart on the sky, offering a fine sight in binoculars and finders. Known throughout recorded history, Arabian stargazers long ago referred to these stars as the "horse and rider," and considered Alcor itself a test of keen vision. However, as Barns pointed out: "Alcor...is no longer the eye-test of ancient days. The pair, so happily placed in the crook of the Big Dipper's handle, never fail to inspire awe, however frequently observed."

Mizar is itself a double star, its 4th magnitude companion lying 15 seconds distant near position angle 150° (southeast on the sky). One of the finest pairs in the sky for a small glass, this radiant duo is exquisite in a 2-inch refractor at just 25 power; grouped with nearby Alcor and an 8th magnitude field star between them, it is a sight never to be forgotten.

All three members of the Mizar-Alcor system are A-type suns and appear white in hue, with perhaps a tinge of blue or green. Smyth logged Mizar's components as "brilliant white, pale emerald," while Olcott found them both white and Muirden both greenish-white. Pickering included this pair on his roster under the category "finest white double stars."

Some 88 light-years distant from us, this system is of considerable historical and astrophysical interest. Mizar was the first double star found with the telescope (by Riccioli in 1662), the first pair ever photographed (by Bond in 1857), and the first spectroscopic binary detected (by Pickering in 1889). In addition, all three visual members are close spectroscopic doubles, meaning that there are at least six suns here where the unaided eye sees only two. If you're one of the few who haven't yet met this remarkable stellar family, why not introduce yourself the next clear night?

Xi (ξ) Ursae Majoris

Overshadowed by the presence of Mizar and Alcor are many other fine double and multiple stars scattered over this month's region. One of the best of these is the tight binary Xi (ξ) Ursae Majoris. To find it, follow a line from Beta (β) in the bowl southward through Psi (ψ), extended again its own length. This brings us to the coarse naked-eye pair of stars Nu (ν) and Xi, separated by 1½° in a north-south direction. Our target is the southern member.

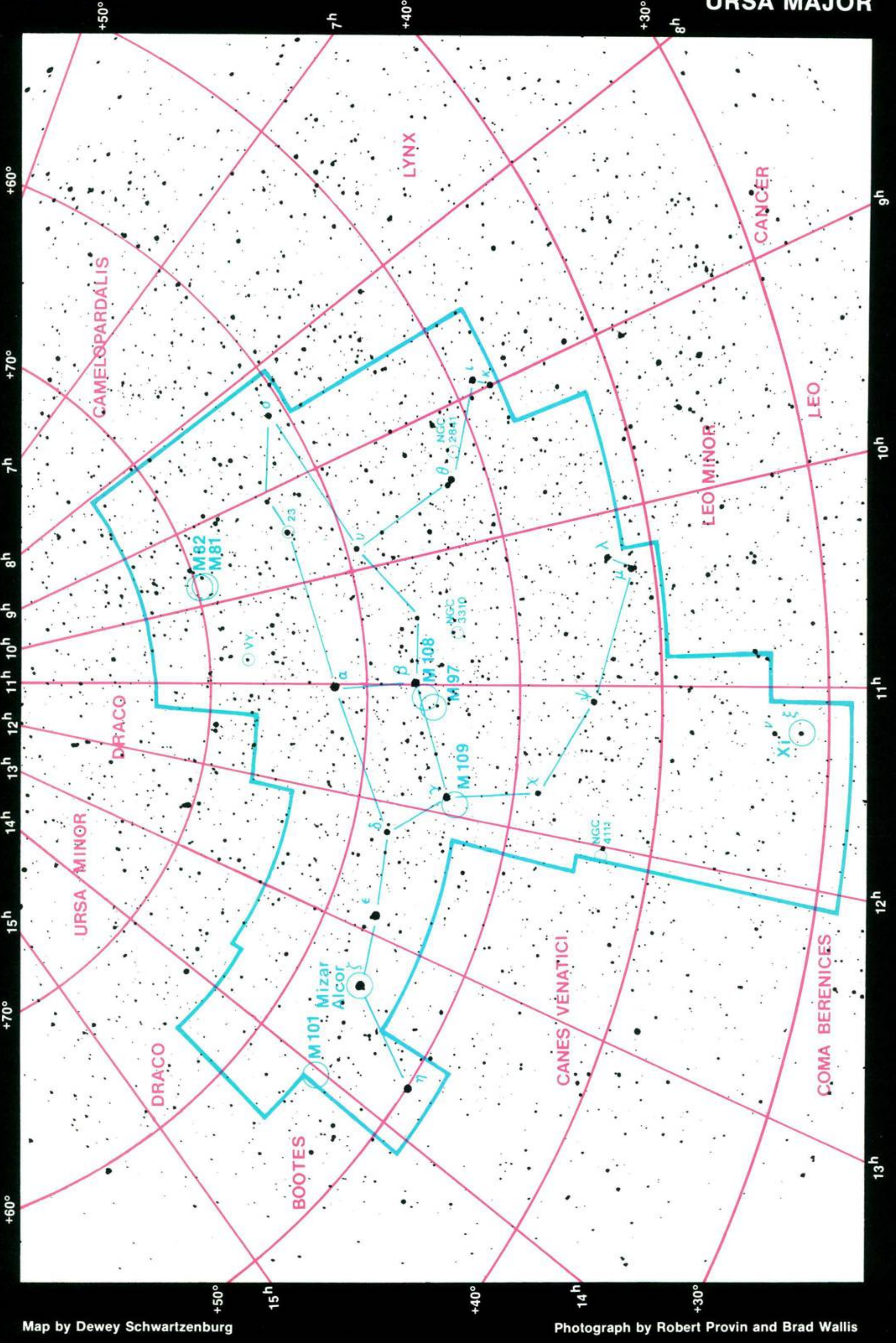
Xi consists of nearly matched golden gems, magnitudes 4.4 and 4.8, currently just under 3 seconds apart in position angle 107°. While a 3-inch refractor at 100 power or more resolves this pair on a steady night, they remain tightly bound even in a 6-inch at medium magnification under average conditions.

Discovered by William Herschel in 1780, Xi is the first visual binary to have its orbit calculated (by Savary in 1828). Its period is well established at 60 years, with more than three complete circuits having been completed since first seen. Minimum separation of the components last occurred in 1949 (1.6 seconds) and maximum in 1974 (3.1 seconds). This dynamic duo is now closing to another minimum scheduled for 1992.

Both members of Xi are G-type stars like our Sun and appear yellowish-white or off-white to most observers. Smyth called the tints "subdued white,

Epoch 1950 coordinates

URSA MAJOR



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7h
+40°
+30°
8h
9h
10h
11h
12h
13h
14h
15h
+60°
+70°
LYNX
CANCER
CAMELOPARDALIS
LEO MINOR
LEO
DRACO
URSA MINOR
CANES VENATICI
COMA BERENICES
BOOTES
M82
M81
M108
M97
M109
M101
NGC 2841
NGC 3310
NGC 4111
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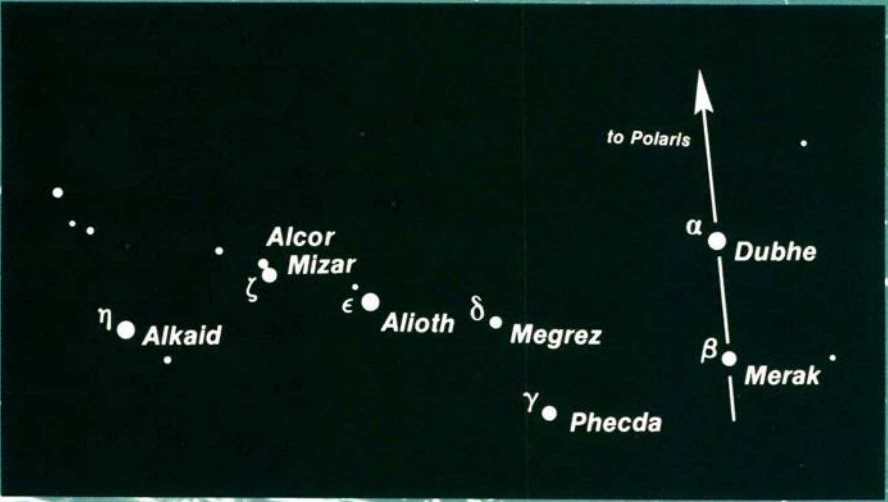

All of the stars in the familiar "Big Dipper" have their own proper names, as well as the Greek letters assigned to them by Bayer in 1603. In Ursa Major, Bayer's Greek letters follow the order of position in the Dipper rather than the order of brightness. Merak and Dubhe are the famous "Pointers," used to locate the north star Polaris (α Ursae Minoris).

greyish white," but few other classic impressions are available. While this pair is found on many lists (including Flammarion's lineup of the 25 best doubles), attention is usually given to the orbital parameters rather than its visual appearance.

Not to be outdone by its illustrious neighbor, Xi's visual components are both spectroscopic binaries having widely disparate periods of 4 and 669 days. This foursome journeys through space together bound by their mutual gravitational attraction, just 26 light-years away from the solar system.

M-97

Nesting in darkness just beneath the Big Dipper's bowl, 2° southeast of Beta, is the well-known Owl Nebula — M-97. To find it, sweep with a low power eyepiece in the telescope on a dark (moonless), transparent night. Easily passed over at first, once seen it is immediately recognizable even in a 2-inch refractor at 30 power under good conditions.

A planetary nebula, M-97 is big for its class, measuring some 200 seconds or 3.3 minutes in diameter. Usually listed as 12th magnitude in catalogs, it is at least a magnitude brighter than this visually. The experienced comet and variable star observer John Bortle rates its integrated light at no less than 9.6 magnitude. However, the large apparent size results in a low surface brightness at the eyepiece (which is what really counts), making this among the more challenging deep-sky objects for the novice.

At least a 6-inch telescope at 50 to 100 power is needed for a good view of the Owl Nebula on an average night. Its pale disk usually appears featureless in amateur instruments, but glimpses of its two dark areas or "eyes" have been reported in apertures as small as 4 inches. They become definite with averted vision in 10 and 12-inch scopes at medium magnification — yet a drawing of this object made by John Herschel with an 18¾ inch reflector fails to show them.

Webb described M-97 as a "Large pale planetary nebula; very remarkable object.... He (John Herschel) saw its light nearly equable, though with softened edge, and faintly bicentral. The Earl of Rosse, on the contrary, two large perforations (whence it has been called the 'Owl Nebula'), and an indistinct spiral structure. Before 1850, there was a star in each opening; since, one only." This last remarkable observation seems to have gone unnoticed by astronomers, reminding us of Pickering's disappearing central star in NGC-3242, the bright planetary in Hydra highlighted in a past installment of Star Dome.

Barns mentions M-97 having "five faint central stars" and a "double formation" as seen in his 10-inch reflector. Can you confirm his observations with your telescope? The Owl appears on Tom Reiland's list of the 35 finest planetaries, compiled with a 6-inch reflector and presented in ASTRONOMY (August 1977). Pickering, however, relegated this object to his showpiece roster's "reject" category, despite the fact that he was using an 11-inch refractor. Which observer's assessment do you agree with?

Norton considered the Owl Nebula large and faint, remarking that a "Large aperture, low power and clear night are required for a good view." Mallas using a 120 power on his 4-inch refractor described it as a "rather large grey oval...practically featureless, though there is a slight indication of two dark areas (the Owl's eyes)." He further stated that he had definitely seen the "eyes" with the same 4-inch instrument from the desert skies of Arizona, but they were not easy.

The distance of M-97 is estimated as anywhere from 2,600 to 12,000 light-years, the lower value being favored. With only one star-filled opening at present, this wise old celestial owl seems to be keeping watch on us with one eye open and the other closed.

M-108

While sweeping for M-97, you may happen upon its neighbor M-108 — a spiral galaxy situated less than a degree from the Owl, about one-third the way from it to Beta Ursae Majoris. This 10.7 magnitude galaxy is often mistaken for the planetary itself, but

Selected Objects — Ursa Major

			Size/Sep.		
Object	Type	Mag.	Per.	R.A. (1950)	Dec.
NGC-2841	§S	9.3	6′x2′	09^h19^m	+51°12′
23	★²	3.8,9.3	23″	09^h28^m	+63°17′
*M-81	§S	7.2	21′x10′	09^h52^m	+69°18′
*M-82	§#	8.7	10′x2′	09^h52^m	+69°56′
NGC-3310	§#	10.1	4′x3′	10^h36^m	+53°46′
VY	∩★	6.0-6.6	--	10^h42^m	+67°40′
*M-108	§S	10.7	8′x1′	11^h09^m	+55°57′
*M-97	■	11	200″	11^h12^m	+55°18′
*Xi (ξ)	★²	4.4,4.8	3″	11^h16^m	+31°49′
*M-109	§S	10.8	6′x4′	11^h55^m	+53°39′
NGC-4111	§0	9.7	3.3′x0.6′	12^h05^m	+43°21′
*Mizar/Alcor	★³	2.3,3.9,4.0	15″,12′	13^h22^m	+55°11′
*M-101	§S	9.6	22′	14^h01^m	+54°35′

*Detailed in Close-Up

§S = **Spiral Galaxy**
★² = **Double Star**
§# = **Peculiar Galaxy**
∩★ = **Irregular Variable**
■ = **Planetary Nebula**
§0 = **Elliptical Galaxy**
★³ = **Triple Star**

its 8 by 1 minute outline is elongated while M-97's is circular. Holyoke noted that M-108 "looks quite like M-97 in a small telescope." Do you agree?

Rediscovered by Herschel, M-108 also carries his designation of Hv-46. Barns found it lying in a "Nebulous region in excelsis!" and Webb saw it as "Large, faint, well-defined, elongated (rather curved); small star in centre." Mallas called it "A silver-white beauty for small telescopes, saucer-shaped and fairly well-defined. The central region is quite bright and irregular, surrounded by light and dark nodules." Despite its distance of 25 million light-years, M-108 can be seen in a 2-inch telescope and makes a good jumping-off point into this region's extragalactic wonderland.

M-81 and M-82

One of the finest and brightest pairs of galaxies in the heavens lies just beyond the bowl of the Big Dipper, within easy reach of small telescopes and even large-aperture binoculars. This is the galactic duo M-81 and M-82. A line extended across the bowl from Gamma (γ) through Alpha (α) and prolonged its length, ends at the 4th magnitude star 24 Ursae Majoris — and our quarry lurks 2° east of this object.

M-81 is a frequently pictured graceful spiral inclined about 45° to our line of sight. Its elliptical 7th magnitude glow measures at least 21 by 10 minutes in size on photos, but only a portion of this visually (as is the case for deep-sky subjects in general). Just over half a degree to the north lies M-82, an 8.7 magnitude cigar-shape some 10 by 2 minutes in extent. Long thought to be an edge-on spiral, it was then reclassified as an irregular system and more recently as a peculiar "exploding" galaxy from its strange appearance on long-exposure photographs. Just recently, it has been returned to its original status as an edge-on spiral, but one undergoing an unusual "burst" of star formation.

As seen in a 3-inch glass at 45 power, M-81 and M-82 are truly stunning and become ever more fascinating as aperture increases. M-81's bright nucleus and surrounding disk are well seen in a 6-inch at 75 to 100 power, while a 10-inch at 80 to 150 diameters gives tantalizing glimpses of the spiral arms themselves in moments of steady air. Rifts of dark obscuring matter can be made out crossing M-82's spindle-shaped form in instruments as small as a 4-inch on a dark night.

Webb's account of this pair was: "Two nebulae ½° apart: 81 bright, with a vivid nucleus, finely grouped with small stars, two of which are projected upon the haze, to which John Herschel gives nearly 15 minutes in length. 82 (Bode's nebula) curious narrow curved ray, d'Arrest 7 minutes by 100 seconds, two nuclei, and sparkling as if resolvable, which 81 is not."

Bernhard, Bennett, and Rice described M-81 as "bright with fine elliptical form, having distinct nuclear area" and M-82 as "long, narrow, and fainter, but an exceptional object crossed by dark bands." Barns logged the duo as "Two nebulae. Argent (silver), 30 minutes apart. Unlike in size, structure, and glow. Worth the search." (This last remark is truly an understatement.) Muirden found them "Visible in the finder. M-81 appears as a circular nebulosity; M-82 has the effect of a narrow, curved streak, somewhat like a scimitar blade." Surprisingly, Pickering was not impressed — he gave them only "runner-up" status in his survey.

An observer who obviously would have disagreed with Pickering was Mallas. His impression of M-81 was: "In the 4-inch refractor, a beautiful object! As seen in that telescope, M-81 has the most strongly granular central region of almost any galaxy. The outer parts are mottled and uneven in brightness and texture. Two other visual characteristics are the fairly sharp outer edge and the bright arcs at the ends of the major axis." M-82 he called "A gem! In a low-powered field, it forms a beautiful pair with M-81. In shape and color M-82 is a silver silver, with its brightest part off center. The dark absorption band... was not detected in the 4-inch. This telescope showed the galaxy to be highly uneven in brightness but with little or none of the grainy texture seen in M-81."

The distance to the M-81/M-82 duo has long been established at 6.5 to 7 million light-years, but a recent determination places it at nearly 10 million. Aside from the great Andromeda Galaxy (M-31) itself, these objects are together the finest specimens of their class for northern hemisphere observers.

M-101

If you are motivated by our last offering to do more galaxy hunting, a good target to try next is the big face-on spiral M-101. (This also happens to be the same object as Messier's 102 — the result of a recording error.) Look for it 5 degrees due east of Mizar and Alcor, forming an equilateral triangle with these stars and Eta (η) at the end of the Dipper's handle.

M-101 is a 9.6 magnitude (some sources consider it at least a magnitude brighter) circular glow some 22 minutes in diameter. Its large apparent extent results in a very low surface brightness and as in the case of M-97, it can be passed over until once recognized. A 3 or 4-inch glass will show it at low power — look for a brightening of the sky in its position, two-thirds the size of the full moon.

Large amateur telescopes can give suggestions of the spiral structure within M-101's circular glow under conditions of both good seeing and transparency. A number of supernovae have occurred here that were within reach of such instruments, and a patrol for possible additional outbursts in this and similar galaxies is an excellent project for the experienced observer having access to a 10-inch or larger scope. A detailed sketch should be made at the eyepiece of all stars visible in and about the galaxy, and then compared carefully to its appearance on subsequent nights. The anticipation of something happening "out there" will add greatly to the pleasure and thrill of viewing these remote star cities scattered across space and time.

Surprisingly, M-101 was omitted by Webb in his work and by many other observers after him. Mallas provided a good modern account: "A beautiful object. In the...4-inch, it appears only about half as large as on photographs. Low powers are best. The clearly seen central region has a fluffy texture and a silvery hue. Surrounding this area is a soft sheen containing some nebulous patches."

This star-studded pinwheel lies some 15 million light-years from us, quietly awaiting your personal inspection.

M-109

Our survey of this month's far-flung region concludes with yet another spiral galaxy — M-109, easily picked up in a 3-inch telescope at 45 power just ½° southeast of Gamma in the bowl. Rediscovered by Herschel, it was catalogued by him as HIV-61, apparently having been mistaken for a planetary nebula (his class IV).

M-109 measures 6 by 4 minutes in size and glows softly at magnitude 10.8. Although considered by Holyoke "One of the most difficult of the Messier objects," Mallas found it "A splendid galaxy for small apertures, though only the brighter central region can be seen. It is pear-shaped, with a strong suspicion of a granular texture, and close to a faint star whose glare obliterates the outer regions." Like M-101, this object is not to be found in Webb or many other classic works — published visual impressions are scarce, presenting an opportunity to fill this gap with those of your own.

Roaming the Ursa Major wonderland on a mild, scented April evening is an exhilarating and uplifting experience — part of what astronomer Gerard de Vaucouleurs calls "the spell with which Astronomy binds its devotees: the fascination and the wonder, not to be put into words, of the contemplation and the understanding of the heavens."

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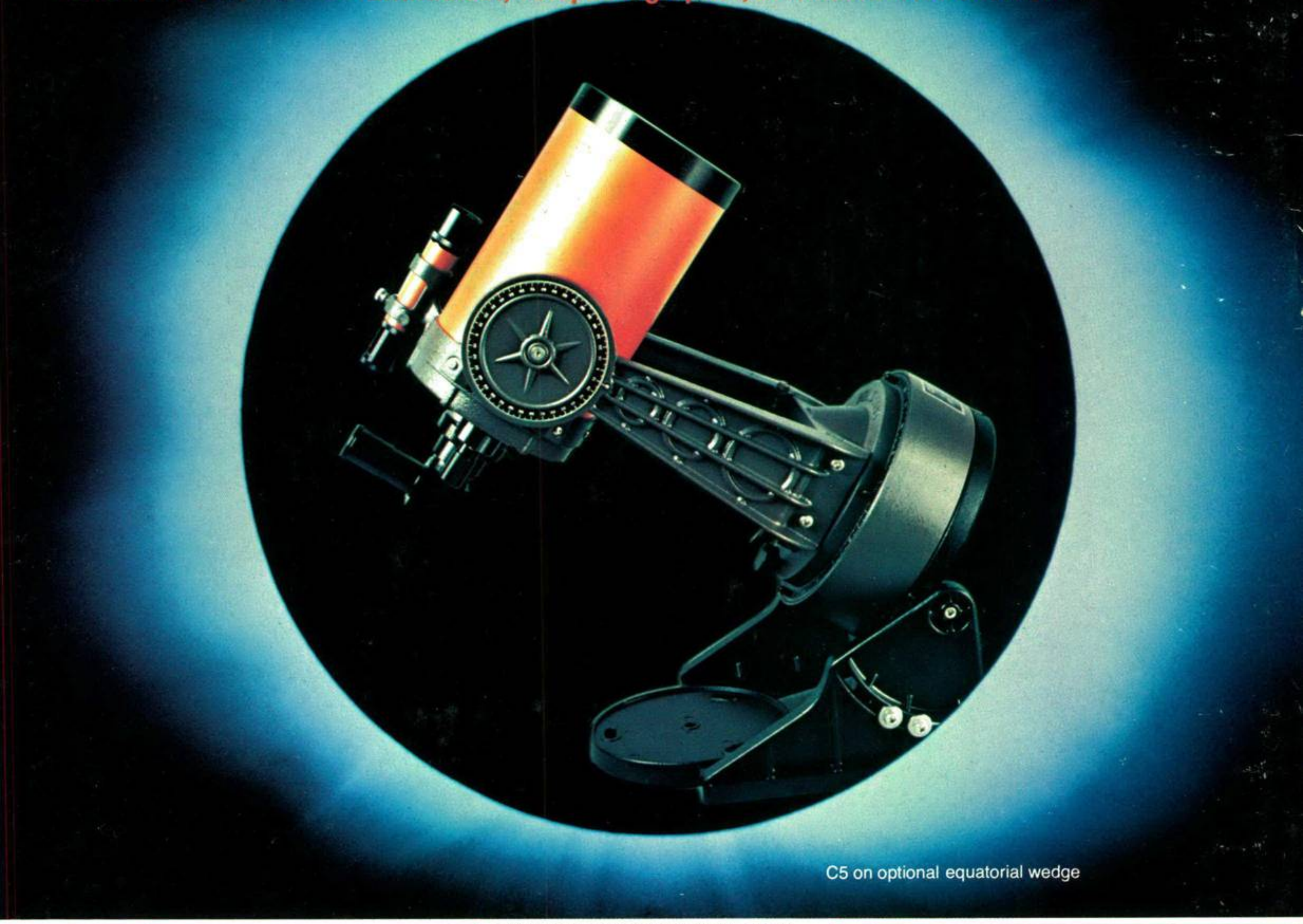

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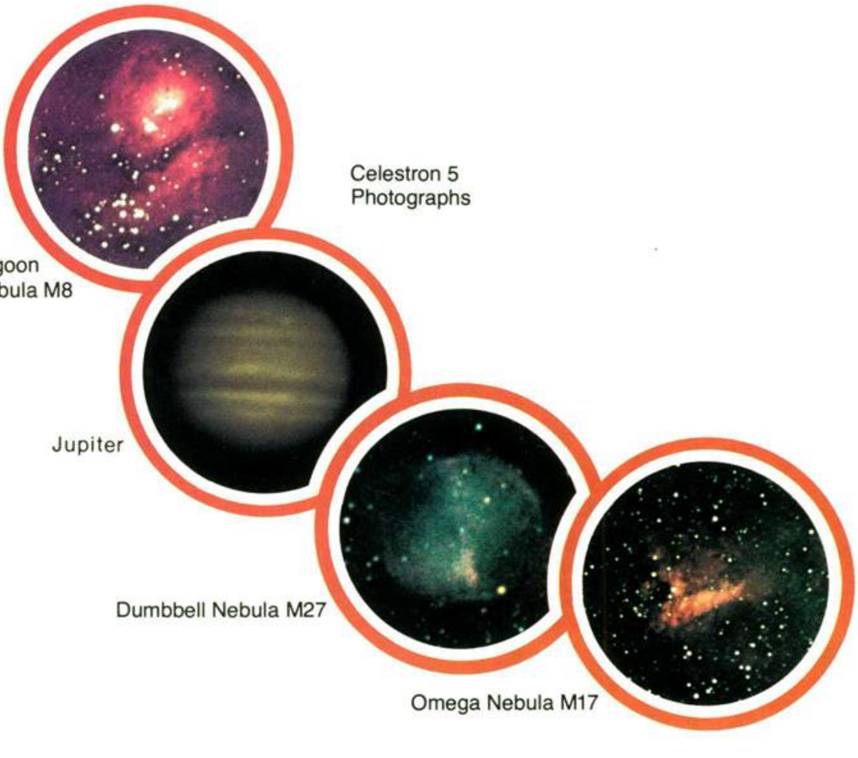

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